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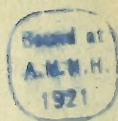


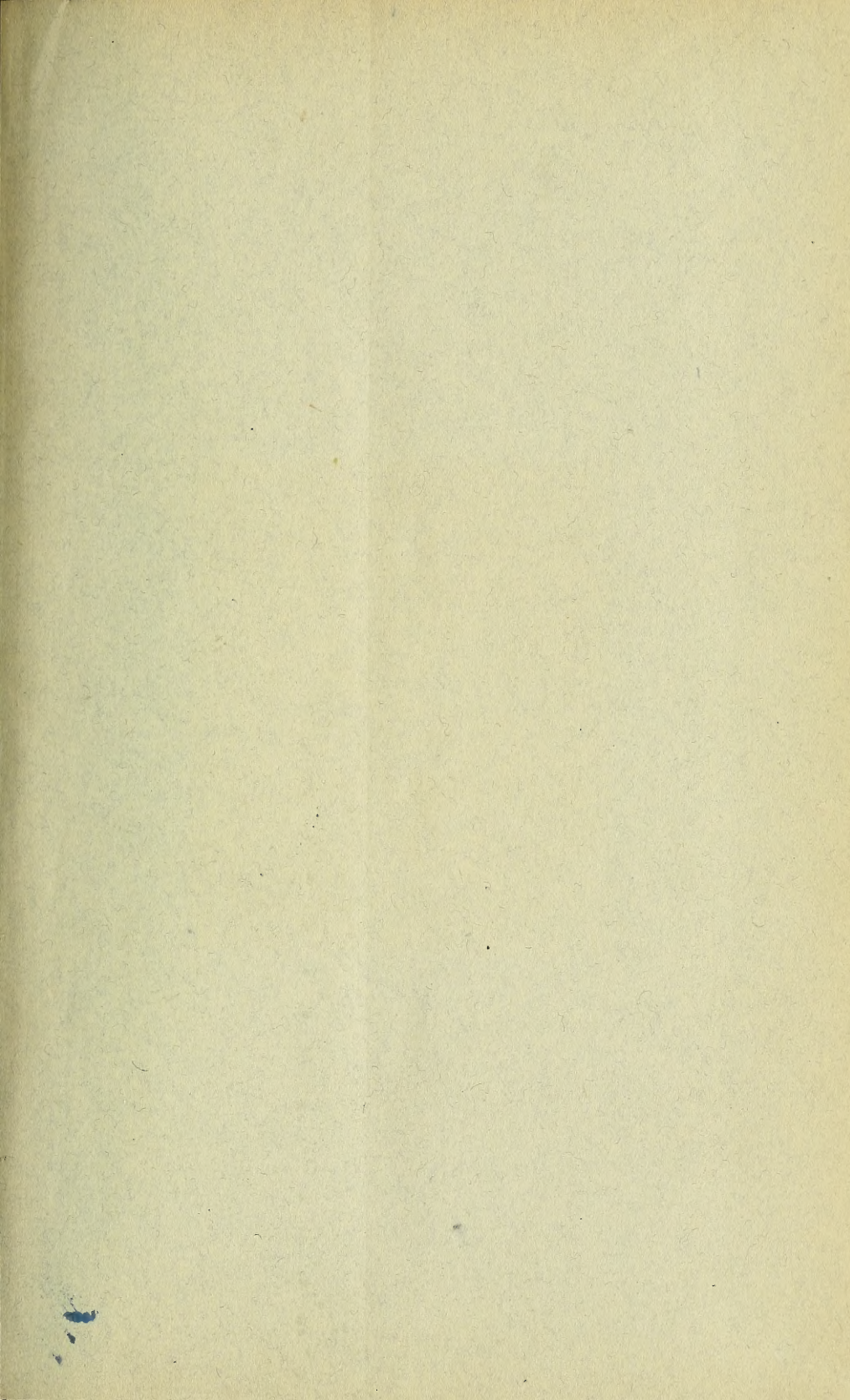
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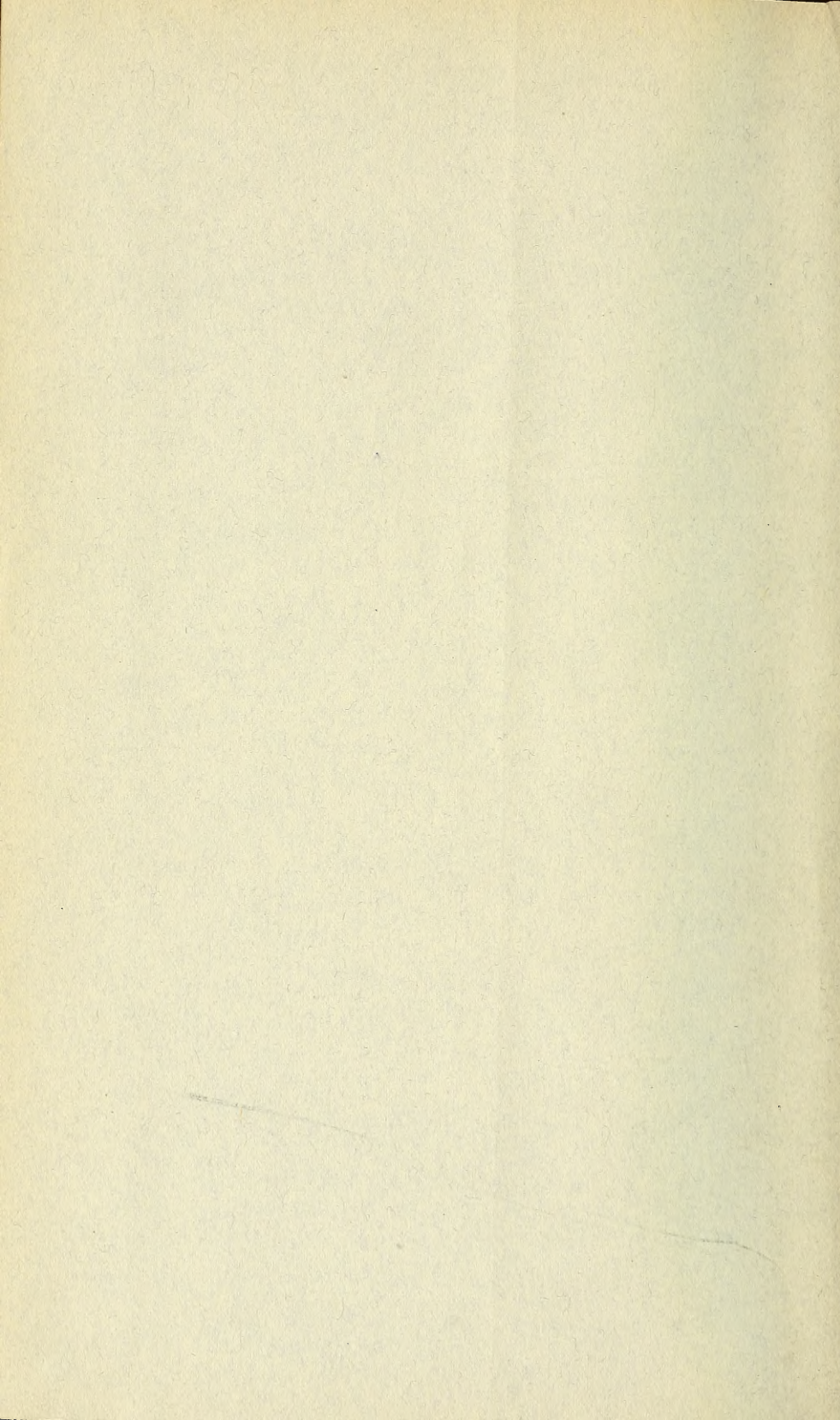
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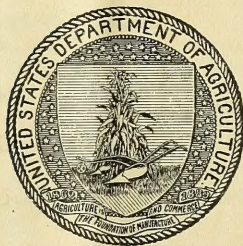
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## VARIATION IN THE CHEMICAL COMPOSITION OF SOILS.

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### INTRODUCTION.

In a previous paper<sup>1</sup> complete analyses of a number of important American soils were presented and discussed chiefly from the point of view of the occurrence of rare elements seldom sought in soils. In that paper, although the analyses were presented under soil-type names and classified by soil provinces, the data were not considered sufficient to warrant any discussion of the chemical variation of soil types or of soil provinces.

Since then, analyses of additional samples, for major constituents only, have been made, and it has seemed that these, together with those already published, might furnish a basis for some general discussion of the variation in chemical composition of American soils.

The additional data, given for the first time in the present paper, include the results of the analysis of 45 samples, representing 18 distinct soil types, distributed in 4 soil provinces. The samples come from 22 different localities in 8 States, and were taken with extreme care by men familiar with the various soils under field conditions.

### DESCRIPTION OF SOILS ANALYZED.

The soil-type names, location, character of samples, and short description of the soils follow:

1. Colorado sand. T. 5 N., R. 65 W. Near Greeley, Col. Soil, depth 0 to 14 inches. This type consists of old stream-borne material derived from the harder

rocks of the Rocky Mountains and deposited over extensive foot slopes, modified in places by residual material from underlying sandstone. It is adapted to fruit and truck crops where not too loose and subject to leaching. The spot where this sample was taken had been cultivated, but supported only weeds at the time the sampling was done. Heavy crops of oats and alfalfa were growing on near-by fields. The sample is typical.

2. Colorado sand, subsoil of No. 1, depth 14 to 36 inches.

3. Oswego silt loam. Two miles northwest of Manhattan, Kans. Depth 0 to 14 inches. This is a dark-gray soil occupying level to gently rolling upland prairies. It is of residual origin and derived from shale, with occasional interbedded layers of sandstone or limestone and in places outcrops of bituminous coal. This sample was taken from a woodlot about 40 years old that had never been in cultivation. The productiveness of this type is fair.

4. Oswego silt loam. Subsoil of No. 3. Depth 14 to 36 inches.

5. Knox silt loam. T. 52 N., R. 34 W., 2 miles north of Farley, Mo. Depth 0 to 14 inches. This soil is formed from wind-deposited glacial material. It occupies rolling to hilly areas which originally supported a hardwood timber growth. The sample was taken on a high bluff from a field supporting a fair growth of clover. This type produces good yields of wheat, corn, clover, and grass.

6. Knox silt loam. Subsoil of No. 5. Depth 14 to 36 inches.

7. Memphis silt loam. Five miles southwest of Granada, Miss. Depth 0 to 6 inches. This type occupies uplands and is subject to serious erosion. It is a productive soil.

8. Memphis silt loam. Subsoil of No. 7. Depth 6 to 36 inches.

9. Memphis silt loam, smooth phase. Five miles northwest of Fort Gaines, Miss. There is very little difference between this soil and No. 7, except the difference in topography indicated by the name. This sample is a shade lighter than the typical. The subsoil is the same as that of typical specimens. The locality would indicate the close relationship between the soils. The productivity is good.

10. Memphis silt loam, smooth phase. Subsoil of No. 9. Depth 6 to 36 inches.

11. Cahaba fine sandy loam. Three miles northwest of Fort Gaines, Ga. Depth 0 to 12 inches. This type is alluvial in origin and occupies the older and higher terraces along the larger streams in the Coastal Plain of the Gulf States. It is a very important agricultural soil. The sample is typical, with the exception that the soil is somewhat too brown and the subsoil is nearly as red as the Orangeburg.

12. Cahaba fine sandy loam. Subsoil of No. 11. Depth 12 to 36 inches.

13. Cahaba very fine sandy loam. Minden, La. Depth 0 to 12 inches. This soil is formed in the same way as the Cahaba fine sandy loam, and except for its finer texture has the same characteristics. Soil and subsoil are typical.

14. Cahaba very fine sandy loam. Subsoil of No. 13. Depth 12 to 36 inches.

15. Norfolk sand. Near Montrose, S. C. Depth 0 to 8 inches. This type is formed from worked-over material coming from the higher-lying provinces. It is not possible to trace its origin to any particular rock or formation. This type is not productive except when heavily fertilized. The sample analyzed was typical as regards the soil, but the subsoil was not so yellow as the typical subsoil.

16. Norfolk sand. Subsoil of No. 15. Depth 8 to 36 inches.

17. Orangeburg sand. One mile east of Day School, Terrell County, Ga. Depth 0 to 10 inches. This type is formed from the worked-over material of the higher provinces. Its reddish color is characteristic. The subsoil is a reddish sand underlain at a depth of 3 feet or more by a reddish sandy clay. It is not productive, except where it is well fertilized. The sample is typical.

18. Orangeburg sand. Subsoil of No. 17. Depth 10 to 36 inches.

19. Orangeburg sandy loam. Two miles east of Fort Gaines, Ga. Depth 0 to 12 inches. The type consists of a medium grayish brown to reddish-brown sand or light sandy loam, from 4 to 5 inches deep, resting on a red sandy clay subsoil usually



containing small gravel and iron concretions. It is of moderate productiveness, but needs applications of complete fertilizer to give the best results. The sample analyzed was typical. There were iron concretions in this sample having well-polished surfaces.

20. Orangeburg sandy loam. Subsoil of No. 19. Depth 12 to 36 inches.

21. Greenville sandy loam. Two miles east of Fort Gaines, Ga. Depth 0 to 10 inches. The soil consists of a reddish-brown medium sandy loam, with a brick-red sticky sand to sandy loam subsoil, becoming heavier with depth. It is of sedimentary origin and derived from unconsolidated deposits of the Coastal Plain. This soil is one of the most productive soils of the upland Coastal Plain region. The sample analyzed was typical. There were in this sample iron concretions of about the same size and abundance as in the Orangeburg sandy loam. The surfaces of these concretions, however, were rough, inclosing soil grains on the surface, which indicates that the process of formation is still going on, or that the concretions in the Orangeburg sample had been polished by water action since their formation.

22. Greenville sandy loam. Subsoil of No. 21. Depth 10 to 36 inches.

23. Norfolk fine sandy loam. One mile north of Elza, Ga. Depth 0 to 10 inches. This is a pale-yellow to gray fine sandy loam, underlain by a yellow fine sandy loam which grades into a light sandy clay at an average depth of 18 inches. It is derived from reworked material carried from the higher-lying soil provinces. This soil is of moderate productiveness. The sample analyzed was typical, except that the subsoil was more brownish red than yellow.

24. Norfolk fine sandy loam. Subsoil of No. 23. Depth 10 to 36 inches.

25. Norfolk fine sandy loam. Three miles southwest of Murphy, Ga. Depth 0 to 16 inches. The general description given for No. 23 applies equally well to this sample. The soil is somewhat too brown and the subsoil more brown than yellow, otherwise the sample is typical.

26. Norfolk fine sandy loam. Subsoil of Sample No. 25. Depth 10 to 36 inches.

27. Tifton fine sandy loam. One and three-fourths miles northeast of Bellville, Ga. Depth 0 to 12 inches. This type consists of a gray or yellowish-gray medium sandy loam, overlying an ochereous-yellow, heavier and more compact medium sandy loam. Both soil and subsoil contain iron concretions and the type is known as pimply land. The type is derived from unconsolidated Coastal Plain deposits. The Tifton soils are somewhat more productive than the Norfolk soils. The sample analyzed is typical, except for a slightly redder shade in the subsoil.

28. Tifton fine sandy loam. Subsoil of No. 27. Depth 12 to 36 inches.

29. Ruston fine sandy loam. One mile south of Minden, La. Depth 0 to 6 inches. The soil of this type is a light-gray or yellowish-gray fine sandy loam, underlain by a buff or reddish-yellow, somewhat mottled heavy fine sandy loam or sandy clay. The type is derived from unconsolidated sediments of the Eocene period modified by an admixture of Lafayette material. The productiveness is low. Both soil and subsoil are typical.

30. Ruston fine sandy loam. Subsoil of No. 29. Depth 6 to 36 inches.

31. Ruston fine sandy loam. One and one-fourth miles northeast of Bluffton, Ga. Depth 0 to 10 inches. The description given for No. 29 applies to this sample, which, however, approaches the Orangeburg in color characteristics, the soil being browner and the subsoil redder than normal. Otherwise the sample is typical.

32. Ruston fine sandy loam. Subsoil of No. 31. Depth 10 to 36 inches.

33. Susquehanna fine sandy loam. Two and one-half miles north of courthouse, Smith County, Tex. Depth 0 to 12 inches. The soil is a gray to brown fine sand or light fine sandy loam, resting on a red or yellowish clay, which is usually stiff and plastic and mottled in the lower depths. Iron concretions are found throughout the soil profile. The type has been derived principally from the underlying clays. It is rated as of medium productivity. The soil and subsoil are typical.

34. Susquehanna fine sandy loam. Subsoil of No. 33. Depth 12 to 36 inches.

35. Susquehanna fine sandy loam. Eight miles northeast of Shubuta, Miss. Depth 0 to 10 inches. The description of No. 33 applies to this sample. Both soil and subsoil are typical.

36. Susquehanna fine sandy loam. Subsoil of No. 35. Depth 10 to 36 inches.

37. Susquehanna fine sandy loam. Four miles south of Hartsfield, Ga. Depth 0 to 12 inches. The description of No. 33 also applies to this sample. The subsoil does not seem to be as highly plastic as the average of the type; otherwise the sample is typical.

38. Susquehanna fine sandy loam. Subsoil of No. 37. Depth 12 to 36 inches.

39. Portsmouth fine sandy loam. Two miles south of Murphy, Ga. Depth 0 to 12 inches. This is a black to rusty-brown, mucky, fine sandy loam, compact and heavy when wet. Large quantities of organic matter in all stages of decomposition are present. The type is formed from the worked-over material of the higher-lying provinces. When drainage conditions are favorable, the fertility is fair. The soil and subsoil are typical.

40. Portsmouth fine sandy loam. Subsoil of No. 39. Depth 12 to 36 inches.

41. Susquehanna clay. Three miles east of Shubuta, Miss. Depth 0 to 4 inches. The soil of this type is a clay loam, sometimes containing gravel, and the subsoil a stiff, tenacious, red and mottled clay. It is formed from unconsolidated deposits of the Coastal Plain. The soil is very refractory and hard to cultivate and at present has very little agricultural value. The sample, both soil and subsoil, are typical.

42. Susquehanna clay. Subsoil of No. 41. Depth 4 to 36 inches.

43. Coxville fine sandy loam. Florence, S. C. Depth 0 to 8 inches. The soil of this type consists of a gray to dark-gray moderately heavy fine sandy loam overlying a stiff, rather plastic clay, which ranges in color from yellow in the upper part to mottled yellow, drab, and bright red in the lower section. Small iron concretions and quartz gravel are sometimes encountered in both soil and subsoil. In productivity it is only fair. This soil is derived from unconsolidated deposits of the Coastal Plain province.

44. Coxville fine sandy loam. Subsoil of No. 43. Depth 8 to 16 inches.

45. Coxville fine sandy loam. Lower subsoil of No. 43. Depth 16 to 36 inches.

#### PREPARATION OF SAMPLES AND METHODS OF ANALYSIS.

The preparation of the samples for analysis was essentially that described in the previous report<sup>1</sup> and the methods of analysis were those used in the analysis of silicate rocks followed in the previous work, and described in detail by Hildebrand.<sup>2</sup>

In carrying on this work the authors gave considerable attention to the limits of error in the more important determinations involved in soil analysis, and lest too much significance be attached to small differences they feel warranted in making the following statement. When working on the same sample of a soil of average composition the determinations of two analysts who have had experience with the methods used should not differ more than 0.50 per cent in the case of  $\text{SiO}_2$ , 0.05 in the case of  $\text{TiO}_2$ , 0.20  $\text{Al}_2\text{O}_3$ , 0.15  $\text{Fe}_2\text{O}_3$ , 0.003  $\text{MnO}$ , 0.10  $\text{CaO}$ , 0.15  $\text{MgO}$ , 0.05  $\text{K}_2\text{O}$ , 0.05  $\text{Na}_2\text{O}$ , and 0.04  $\text{P}_2\text{O}_5$ , these figures being percentage of soil, not percentage variation. Duplicates by the same analyst should of course agree more closely. Variations in the solubility of glassware were found to be a most frequent source of disagreement in  $\text{CaO}$  and  $\text{MgO}$  determination.

<sup>1</sup> U. S. Dept. Agr. Bul. No. 122 (1914).

<sup>2</sup> U. S. Geol. Survey Bul. 422 (1910).

The method used for determining phosphorus was tested on synthetic mixtures, and as a result it is estimated that the figures given for phosphoric acid are within 0.02 per cent of the actual amount present.

Blank determinations were made in all cases, and the silica and magnesia corrected for impurities. The quantity of silica in the iron and alumina group precipitate had been found constantly so small in earlier work that no correction was made for it here.

### RESULTS OF ANALYSES.

The results of these analyses are given in the following table. The results are stated in percentage of the soil dried at 105° C.

TABLE 1.—*Chemical analyses of certain American soils.*

[Analyses by W. O. Robinson and L. A. Steinkoenig; nitrogen determinations by Wm. H. Fry.]

| Constituent.                         | Great Plains Province. |               |                   |               | Glacial and Loessial Province. |               |                    |              |                                  |              |
|--------------------------------------|------------------------|---------------|-------------------|---------------|--------------------------------|---------------|--------------------|--------------|----------------------------------|--------------|
|                                      | Colorado sand.         |               | Oswego silt loam. |               | Knox silt loam.                |               | Memphis silt loam. |              | Memphis silt loam, smooth phase. |              |
|                                      | (1)                    | (2)           | (3)               | (4)           | (5)                            | (6)           | (7)                | (8)          | (9)                              | (10)         |
|                                      | 0-14 inches.           | 14-36 inches. | 0-14 inches.      | 14-36 inches. | 0-14 inches.                   | 14-36 inches. | 0-6 inches.        | 6-36 inches. | 0-6 inches.                      | 6-36 inches. |
| SiO <sub>2</sub> .....               | P. ct. 78.85           | P. ct. 76.84  | P. ct. 71.38      | P. ct. 68.74  | P. ct. 76.81                   | P. ct. 75.95  | P. ct. 81.13       | P. ct. 73.58 | P. ct. 80.78                     | P. ct. 72.67 |
| TiO <sub>2</sub> .....               | 0.32                   | 0.36          | 0.68              | 0.70          | 0.70                           | 0.70          | 0.78               | 0.80         | 0.86                             | 0.79         |
| Al <sub>2</sub> O <sub>3</sub> ..... | 9.68                   | 11.09         | 12.29             | 14.45         | 9.73                           | 11.16         | 8.52               | 12.25        | 8.48                             | 12.80        |
| Fe <sub>2</sub> O <sub>3</sub> ..... | 2.72                   | 3.21          | 3.63              | 5.00          | 3.26                           | 3.99          | 2.92               | 5.02         | 3.05                             | 5.58         |
| MnO.....                             | 0.031                  | 0.036         | 0.056             | 0.057         | 0.068                          | 0.067         | 0.027              | 0.067        | 0.036                            | 0.052        |
| CaO.....                             | 0.94                   | 1.08          | 1.09              | 0.88          | 0.92                           | 0.92          | 0.31               | 0.36         | 0.27                             | 0.26         |
| MgO.....                             | 0.72                   | 0.62          | 0.36              | 1.12          | 0.60                           | 0.74          | 0.39               | 0.78         | 0.45                             | 0.84         |
| K <sub>2</sub> O.....                | 2.31                   | 2.57          | 2.28              | 2.20          | 2.10                           | 1.60          | 1.78               | 2.14         | 1.84                             | 2.08         |
| Na <sub>2</sub> O.....               | 2.02                   | 2.06          | 1.14              | 1.12          | 1.74                           | 1.74          | 0.52               | 0.71         | 0.72                             | 0.56         |
| P <sub>2</sub> O <sub>5</sub> .....  | 0.11                   | 0.09          | 0.10              | 0.08          | 0.12                           | 0.10          | 0.08               | 0.14         | 0.10                             | 0.13         |
| SO <sub>3</sub> .....                | 0.07                   | 0.20          | 0.12              | 0.18          | 0.11                           | 0.02          | 0.03               | 0.02         | 0.03                             | 0.04         |
| N.....                               | 0.10                   | 0.07          | 0.20              | 0.13          | 0.14                           | 0.06          | 0.11               | 0.07         | 0.06                             | 0.05         |
| Loss on ignition.....                | 2.28                   | 2.35          | 7.11              | 5.49          | 4.09                           | 2.77          | 3.40               | 4.01         | 3.20                             | 3.96         |

| Constituent.                         | River Flood Plains Province. |               |                              |               | Coastal Plain Province. |              |                  |               |                        |               |                        |               |
|--------------------------------------|------------------------------|---------------|------------------------------|---------------|-------------------------|--------------|------------------|---------------|------------------------|---------------|------------------------|---------------|
|                                      | Cahaba fine sandy loam.      |               | Cahaba very fine sandy loam. |               | Norfolk sand.           |              | Orangeburg sand. |               | Orangeburg sandy loam. |               | Greenville sandy loam. |               |
|                                      | (11)                         | (12)          | (13)                         | (14)          | (15)                    | (16)         | (17)             | (18)          | (19)                   | (20)          | (21)                   | (22)          |
|                                      | 0-12 inches.                 | 12-36 inches. | 0-12 inches.                 | 12-36 inches. | 0-8 inches.             | 8-36 inches. | 0-10 inches.     | 10-36 inches. | 0-12 inches.           | 12-36 inches. | 0-10 inches.           | 10-36 inches. |
| SiO <sub>2</sub> .....               | P. ct. 91.39                 | P. ct. 73.25  | P. ct. 93.29                 | P. ct. 91.83  | P. ct. 94.81            | P. ct. 97.01 | P. ct. 96.18     | P. ct. 91.86  | P. ct. 94.32           | P. ct. 77.20  | P. ct. 92.42           | P. ct. 73.03  |
| TiO <sub>2</sub> .....               | 0.52                         | 0.69          | 0.42                         | 0.46          | 0.51                    | 0.53         | 0.35             | 0.41          | 0.40                   | 0.66          | 0.41                   | 0.70          |
| Al <sub>2</sub> O <sub>3</sub> ..... | 3.72                         | 13.79         | 2.45                         | 3.83          | 1.42                    | 1.31         | 1.70             | 4.11          | 2.13                   | 12.75         | 2.78                   | 16.11         |
| Fe <sub>2</sub> O <sub>3</sub> ..... | 0.97                         | 4.88          | 0.78                         | 1.19          | 0.60                    | 0.52         | 0.59             | 1.32          | 0.85                   | 3.18          | 1.55                   | 5.11          |
| MnO.....                             | 0.065                        | 0.024         | 0.066                        | 0.079         | 0.028                   | 0.095        | 0.016            | 0.011         | 0.054                  | 0.027         | 0.030                  | 0.016         |
| CaO.....                             | 0.21                         | 0.15          | 0.15                         | 0.12          | 0.19                    | 0.03         | 0.08             | 0.05          | 0.05                   | 0.09          | 0.01                   | 0.10          |
| MgO.....                             | 0.09                         | 0.34          | 0.01                         | 0.09          | 0.01                    | 0.01         | Trace.           | Trace.        | Trace.                 | 0.08          | Trace.                 | 0.23          |
| K <sub>2</sub> O.....                | 0.90                         | 1.08          | 0.45                         | 0.58          | 0.08                    | 0.08         | 0.03             | 0.10          | 0.10                   | 0.14          | 0.13                   | 0.14          |
| Na <sub>2</sub> O.....               | 0.12                         | 0.10          | 0.03                         | 0.05          | 0.12                    | 0.08         | Trace.           | Trace.        | 0.29                   | 0.20          | 0.26                   | 0.26          |
| P <sub>2</sub> O <sub>5</sub> .....  | 0.06                         | 0.05          | 0.06                         | 0.05          | 0.10                    | 0.03         | 0.04             | 0.04          | 0.05                   | 0.08          | 0.05                   | 0.06          |
| SO <sub>3</sub> .....                | 0.06                         | 0.05          | 0.10                         | 0.13          | 0.08                    | 0.06         | 0.07             | 0.10          | 0.07                   | 0.11          | 0.02                   | 0.05          |
| N.....                               | 0.05                         | 0.10          | 0.05                         | 0.03          | 0.05                    | 0.02         | 0.06             | 0.02          | 0.03                   | 0.08          | 0.02                   | 0.03          |
| Loss on ignition.....                | 1.53                         | 5.18          | 2.12                         | 1.61          | 2.33                    | 0.79         | 1.03             | 1.75          | 1.69                   | 5.19          | 2.00                   | 5.46          |



TABLE 1.—*Chemical analyses of certain American soils—Continued.*

| Constituent.                         | Coastal Plain Province—Continued. |               |                          |               |                         |               |                         |               |                         |               |                              |               |
|--------------------------------------|-----------------------------------|---------------|--------------------------|---------------|-------------------------|---------------|-------------------------|---------------|-------------------------|---------------|------------------------------|---------------|
|                                      | Norfolk fine sandy loam.          |               | Norfolk fine sandy loam. |               | Tifton fine sandy loam. |               | Ruston fine sandy loam. |               | Ruston fine sandy loam. |               | Susquehanna fine sandy loam. |               |
|                                      | (23)                              | (24)          | (25)                     | (26)          | (27)                    | (28)          | (29)                    | (30)          | (31)                    | (32)          | (33)                         | (34)          |
|                                      | 0-10 inches.                      | 10-36 inches. | 0-16 inches.             | 16-36 inches. | 0-12 inches.            | 12-36 inches. | 0-6 inches.             | 6-36 inches.  | 0-10 inches.            | 10-36 inches. | 0-12 inches.                 | 12-36 inches. |
|                                      | <i>P. ct.</i>                     | <i>P. ct.</i> | <i>P. ct.</i>            | <i>P. ct.</i> | <i>P. ct.</i>           | <i>P. ct.</i> | <i>P. ct.</i>           | <i>P. ct.</i> | <i>P. ct.</i>           | <i>P. ct.</i> | <i>P. ct.</i>                | <i>P. ct.</i> |
| SiO <sub>2</sub> .....               | 95.54                             | 90.60         | 92.87                    | 89.04         | 94.15                   | 76.29         | 95.51                   | 85.95         | 90.22                   | 74.80         | 90.90                        | 67.55         |
| TiO <sub>2</sub> .....               |                                   |               |                          |               |                         |               |                         |               |                         |               |                              |               |
| Al <sub>2</sub> O <sub>3</sub> ..... | 1.70                              | 5.57          | 0.43                     | 0.55          | 0.41                    | 0.73          | 0.36                    | 0.60          | 4.26                    | 15.40         | 0.57                         | 0.82          |
| Fe <sub>2</sub> O <sub>3</sub> ..... | 0.62                              | 1.19          | 2.75                     | 5.36          | 1.67                    | 12.51         | 1.70                    | 6.75          |                         |               | 2.59                         | 16.08         |
| MnO.....                             | 0.020                             | 0.007         | 1.17                     | 2.04          | 0.94                    | 4.01          | 0.68                    | 2.65          | 1.52                    | 4.09          | 3.02                         | 7.52          |
| CaO.....                             | 0.06                              | 0.03          | 0.03                     | 0.01          | 0.05                    | 0.07          | 0.12                    | 0.12          | 0.06                    | 0.02          | 0.11                         | 0.16          |
| MgO.....                             | Trace.                            | 0.04          | Trace.                   | 0.07          | Trace.                  | 0.15          | Trace.                  | 0.18          | 0.01                    | 0.04          | 0.09                         | 0.60          |
| K <sub>2</sub> O.....                | 0.06                              | 0.12          | 0.05                     | 0.10          | 0.10                    | 0.12          | 0.16                    | 0.36          | 0.12                    | 0.08          | 0.28                         | 0.66          |
| Na <sub>2</sub> O.....               | 0.18                              | 0.14          | 0.01                     | Trace.        | Trace.                  | Trace.        | 0.04                    | 0.04          | 0.14                    | 0.10          | Trace.                       | Trace.        |
| P <sub>2</sub> O <sub>5</sub> .....  | 0.05                              | 0.04          | 0.04                     | 0.03          | 0.04                    | 0.05          | 0.04                    | 0.05          | 0.05                    | 0.07          | 0.04                         | 0.05          |
| SO <sub>3</sub> .....                | 0.03                              | 0.04          | 0.05                     | 0.06          | 0.06                    | 0.07          | 0.23                    | 0.13          | 0.04                    | 0.05          | 0.07                         | 0.05          |
| N.....                               | 0.06                              | 0.02          | 0.04                     | 0.05          | 0.04                    | 0.04          | 0.07                    | 0.03          | 0.05                    | 0.03          | 0.08                         | 0.05          |
| Loss on ignition.....                | 1.94                              | 2.37          | 2.35                     | 2.55          | 2.31                    | 5.78          | 1.49                    | 3.15          | 3.59                    | 5.71          | 2.21                         | 6.75          |

| Constituent.                         | Coastal Plain Province—Concluded. |               |                              |               |                             |               |                   |               |                           |               |               |
|--------------------------------------|-----------------------------------|---------------|------------------------------|---------------|-----------------------------|---------------|-------------------|---------------|---------------------------|---------------|---------------|
|                                      | Susquehanna fine sandy loam.      |               | Susquehanna fine sandy loam. |               | Portsmouth fine sandy loam. |               | Susquehanna clay. |               | Coxville fine sandy loam. |               |               |
|                                      | (35)                              | (36)          | (37)                         | (38)          | (39)                        | (40)          | (41)              | (42)          | (43)                      | (44)          | (45)          |
|                                      | 0-10 inches.                      | 10-36 inches. | 0-12 inches.                 | 12-36 inches. | 0-12 inches.                | 12-36 inches. | 0-4 inches.       | 4-36 inches.  | 0-8 inches.               | 8-16 inches.  | 16-36 inches. |
|                                      | <i>P. ct.</i>                     | <i>P. ct.</i> | <i>P. ct.</i>                | <i>P. ct.</i> | <i>P. ct.</i>               | <i>P. ct.</i> | <i>P. ct.</i>     | <i>P. ct.</i> | <i>P. ct.</i>             | <i>P. ct.</i> | <i>P. ct.</i> |
| SiO <sub>2</sub> .....               | 91.37                             | 67.47         | 91.17                        | 75.04         | 94.85                       | 94.61         | 76.67             | 62.07         | 92.92                     | 92.81         | 80.63         |
| TiO <sub>2</sub> .....               |                                   |               |                              |               |                             |               |                   |               |                           |               |               |
| Al <sub>2</sub> O <sub>3</sub> ..... | 2.78                              | 0.73          | 0.42                         | 0.82          | 0.56                        | 0.56          | 1.02              | 1.00          | 0.84                      | 0.96          | 1.16          |
| Fe <sub>2</sub> O <sub>3</sub> ..... |                                   | 14.88         | 3.65                         | 13.38         | 1.37                        | 2.97          | 8.98              | 18.45         | 1.19                      | 3.65          | 11.03         |
| MnO.....                             | 3.00                              | 9.43          | 1.31                         | 5.04          | 0.41                        | 0.33          | 6.05              | 8.42          | 0.58                      | 0.77          | 2.61          |
| CaO.....                             | 0.013                             | 0.006         | 0.068                        | 0.007         | 0.003                       | 0.002         | 0.097             | 0.013         | 0.010                     | 0.005         | 0.005         |
| CaO.....                             | 0.04                              | 0.10          | Trace.                       | Trace.        | Trace.                      | Trace.        | 0.40              | 0.37          | 0.05                      | 0.08          | 0.08          |
| MgO.....                             | 0.03                              | 0.52          | Trace.                       | Trace.        | Trace.                      | Trace.        | 0.32              | 0.67          | 0.01                      | 0.01          | Trace.        |
| K <sub>2</sub> O.....                | 0.10                              | 0.46          | 0.12                         | 0.16          | 0.06                        | 0.02          | 0.56              | 0.76          | 0.08                      | 0.06          | 0.08          |
| Na <sub>2</sub> O.....               | 0.12                              | Trace.        | Trace.                       | 0.01          | 0.06                        | 0.02          | 0.01              | 0.02          | 0.12                      | 0.06          | 0.14          |
| P <sub>2</sub> O <sub>5</sub> .....  | 0.09                              | 0.10          | 0.04                         | 0.10          | 0.05                        | 0.06          | 0.06              | 0.05          | 0.04                      | 0.03          | 0.04          |
| SO <sub>3</sub> .....                | 0.08                              | 0.07          | 0.08                         | 0.04          | 0.03                        | 0.03          | 0.04              | 0.05          | 0.05                      | 0.05          | 0.07          |
| N.....                               | 0.03                              | 0.03          | 0.05                         | 0.01          | 0.05                        | 0.03          | 0.07              | 0.05          | 0.08                      | 0.02          | 0.07          |
| Loss on ignition.....                | 2.26                              | 6.17          | 3.11                         | 5.31          | 2.26                        | 1.61          | 5.42              | 8.09          | 4.46                      | 1.63          | 4.36          |

The previously published data, to which reference has already been made, and which it is proposed to discuss in connection with the analyses presented in the foregoing table, comprise the analyses of twenty-four samples, representing twelve soil types distributed in four soil provinces.

The results of these analyses, for major constituents only, are presented in Table 2.

TABLE 2.—*Chemical analyses of certain American soils.*

[Analyses by W. O. Robinson.]

| Province and type.     | Depth.              | Constituent.         |                                  |                                  |                     |                     |                     |                     |                                 |                     |
|------------------------|---------------------|----------------------|----------------------------------|----------------------------------|---------------------|---------------------|---------------------|---------------------|---------------------------------|---------------------|
|                        |                     | SiO <sub>2</sub> .   | Al <sub>2</sub> O <sub>3</sub> . | Fe <sub>2</sub> O <sub>3</sub> . | CaO.                | MgO.                | K <sub>2</sub> O.   | Na <sub>2</sub> O.  | P <sub>2</sub> O <sub>5</sub> . | SO <sub>3</sub> .   |
| Coastal Plain:         |                     |                      |                                  |                                  |                     |                     |                     |                     |                                 |                     |
| Norfolk sandy loam—    |                     |                      |                                  |                                  |                     |                     |                     |                     |                                 |                     |
| Soil.....              | <i>Inches.</i> 0-14 | <i>Per ct.</i> 94.50 | <i>Per ct.</i> 2.07              | <i>Per ct.</i> 0.83              | <i>Per ct.</i> 0.39 | <i>Per ct.</i> 0.09 | <i>Per ct.</i> 0.10 | <i>Per ct.</i> 0.11 | <i>Per ct.</i> 0.06             | <i>Per ct.</i> 0.07 |
| Subsoil.....           | 14-36               | 85.30                | 8.82                             | 1.91                             | .38                 | .19                 | .12                 | .07                 | .04                             | .13                 |
| Limestone Valleys:     |                     |                      |                                  |                                  |                     |                     |                     |                     |                                 |                     |
| Decatur clay loam—     |                     |                      |                                  |                                  |                     |                     |                     |                     |                                 |                     |
| Soil.....              | 0-4                 | 79.35                | 8.89                             | 4.44                             | .63                 | .39                 | .67                 | .24                 | .18                             | .13                 |
| Subsoil.....           | 4-15                | 74.81                | 12.80                            | 5.28                             | .40                 | .33                 | .75                 | .16                 | .15                             | .19                 |
| Hagerstown loam—       |                     |                      |                                  |                                  |                     |                     |                     |                     |                                 |                     |
| Soil.....              | 0-8                 | 70.99                | 11.39                            | 4.23                             | .93                 | 1.08                | 2.71                | .82                 | .19                             | .34                 |
| Subsoil.....           | 8-24                | 66.49                | 14.80                            | 5.99                             | .35                 | 1.93                | 3.58                | .66                 | .16                             | .14                 |
| Glacial and Loessial:  |                     |                      |                                  |                                  |                     |                     |                     |                     |                                 |                     |
| Volusia silt loam—     |                     |                      |                                  |                                  |                     |                     |                     |                     |                                 |                     |
| Soil.....              | 0-8                 | 75.12                | 10.49                            | 4.13                             | .49                 | .48                 | 1.40                | .90                 | .18                             | .09                 |
| Subsoil.....           | 8-36                | 74.64                | 12.26                            | 5.01                             | .37                 | .90                 | 1.99                | .99                 | .15                             | .10                 |
| Marshall silt loam—    |                     |                      |                                  |                                  |                     |                     |                     |                     |                                 |                     |
| Soil.....              | 0-15                | 75.61                | 9.67                             | 3.54                             | 1.08                | .77                 | 2.28                | 1.03                | .22                             | .17                 |
| Subsoil.....           | 15-36               | 71.43                | 13.44                            | 4.28                             | 1.40                | 1.28                | 2.03                | .63                 | .16                             | .14                 |
| Gloucester stony loam— |                     |                      |                                  |                                  |                     |                     |                     |                     |                                 |                     |
| Soil.....              | 0-8                 | 65.68                | 14.15                            | 5.67                             | 1.36                | .83                 | 2.16                | 1.39                | .15                             | .17                 |
| Subsoil.....           | 8-36                | 73.80                | 13.24                            | 4.37                             | 1.19                | .39                 | 2.22                | 1.75                | .11                             | .03                 |
| Piedmont Plateau:      |                     |                      |                                  |                                  |                     |                     |                     |                     |                                 |                     |
| Cecil clay—            |                     |                      |                                  |                                  |                     |                     |                     |                     |                                 |                     |
| Soil.....              | 0-6                 | 66.49                | 17.11                            | 7.43                             | .36                 | .31                 | .62                 | .16                 | .17                             | .07                 |
| Subsoil.....           | 6-36                | 44.15                | 27.58                            | 16.23                            | .44                 | .09                 | .61                 | .15                 | .15                             | .07                 |
| Cecil sandy loam—      |                     |                      |                                  |                                  |                     |                     |                     |                     |                                 |                     |
| Soil.....              | 0-8                 | 88.57                | 5.76                             | 1.55                             | .39                 | .21                 | .82                 | .16                 | .08                             | .04                 |
| Subsoil.....           | 8-36                | 55.69                | 24.42                            | 8.83                             | .40                 | .29                 | 1.06                | .14                 | .07                             | .09                 |
| Durham sandy loam—     |                     |                      |                                  |                                  |                     |                     |                     |                     |                                 |                     |
| Soil.....              | 0-10                | 80.79                | 10.55                            | 1.61                             | .89                 | .19                 | 3.96                | .87                 | .12                             | .06                 |
| Subsoil.....           | 10-36               | 69.35                | 18.04                            | 3.42                             | .72                 | .29                 | 3.34                | .89                 | .12                             | .06                 |
| York silt loam—        |                     |                      |                                  |                                  |                     |                     |                     |                     |                                 |                     |
| Soil.....              | 0-10                | 76.71                | 12.85                            | 2.81                             | .08                 | .29                 | 3.26                | .39                 | .05                             | .12                 |
| Subsoil.....           | 10-22               | 74.38                | 16.31                            | 2.56                             | .21                 | .38                 | 4.07                | .30                 | .05                             | .14                 |
| Louisa loam—           |                     |                      |                                  |                                  |                     |                     |                     |                     |                                 |                     |
| Soil.....              | 0-12                | 84.58                | 5.54                             | 3.30                             | .21                 | .25                 | .74                 | .14                 | .12                             | .15                 |
| Subsoil.....           | 12-30               | 74.99                | 10.90                            | 6.75                             | .26                 | .32                 | .97                 | .28                 | .15                             | .16                 |
| Penn silt loam—        |                     |                      |                                  |                                  |                     |                     |                     |                     |                                 |                     |
| Soil.....              | 0-9                 | 74.33                | 11.00                            | 4.64                             | 1.13                | .69                 | 1.57                | 1.53                | .16                             | .15                 |
| Subsoil.....           | 9-24                | 71.76                | 14.36                            | 5.82                             | 1.73                | 1.06                | 1.50                | 1.54                | .10                             | .10                 |

## PETROGRAPHIC EXAMINATION.

In the samples analyzed a search was made by the petrographic method for the presence of the more important soil minerals. Those sought for and their formulas are:

Quartz= $\text{SiO}_2$ .

Magnetite= $\text{Fe}_3\text{O}_4$ .

Orthoclase= $\text{KAlSi}_3\text{O}_8$ .

Microcline= $\text{KAlSi}_3\text{O}_8$ .

Biotite=About  $(\text{H}, \text{K})_2(\text{Mg}, \text{Fe})_2\text{Al}_2\text{Si}_3\text{O}_{12}$ .

Muscovite=About  $\text{H}_2\text{KAl}_3\text{Si}_3\text{O}_{12}$ .

Plagioclase=Isomorphous mixtures of  $\text{NaAlSi}_3\text{O}_8$  and  $\text{CaAl}_2\text{Si}_2\text{O}_8$ .

Hornblende=Chiefly  $\text{Ca}(\text{Mg}, \text{Fe})_3\text{Si}_4\text{O}_{12}$  with  $\text{Na}_2\text{Al}_2\text{Si}_4\text{O}_{12}$  and  $(\text{Mg}, \text{Fe})_2(\text{Al}, \text{Fe})_4\text{Si}_2\text{O}_{12}$ .

Epidote= $\text{HCa}_2(\text{Al}, \text{Fe})_3\text{Si}_3\text{O}_{13}$ .

Titanite= $\text{CaTiSiO}_5$ .

Garnet= $\ddot{\text{R}}_3\ddot{\text{R}}_2(\text{SiO}_4)_3$  in which  $\ddot{\text{R}}$  is Ca, Mg, Fe, and Mn, and  $\ddot{\text{R}}$  is Al, Fe, and Cr, and rarely Ti.

Apatite= $(\text{CaF})\text{Ca}_4\text{P}_3\text{O}_{12}$ . F may be replaced by Cl.

Zoisite= $\text{Ca}_2(\text{AlOH})\text{Al}_2(\text{SiO}_4)_3$ .

Cordierite= $\text{H}_2(\text{Mg}, \text{Fe})_4\text{Al}_8\text{Si}_{10}\text{O}_{37}$ .

Chlorite=Probably a mixture of  $\text{H}_4(\text{Mg}, \text{Fe})_3\text{Si}_2\text{O}_9$  and  $\text{H}_4(\text{Mg}, \text{Fe})_2\text{Al}_2\text{SiO}_9$ .

Cyanite= $\text{Al}_2\text{SiO}_5$ .

Sillimanite= $\text{Al}_2\text{SiO}_5$ .

Tourmaline=A complex silicate of B and Al, with Mg, Fe, or the alkali metals prominent.

Rutile= $\text{TiO}_2$ .

Zircon= $\text{ZrSiO}_4$ .

This search, it should be understood, involved an examination of a reasonable number of subsamples and the expenditure of a reasonable time, the results being relative rather than absolute. Experience in this work supports the conclusion that by extending the search indefinitely, nearly all the minerals sought would be found in traces in most soils.

The results of the petrographic examination are presented in Table 3. In this table P. indicates that the mineral is plentiful, S. present in small amounts, VS. in very small amounts, T. in traces. A plus (+) or minus (-) sign after a letter has the usual significance.

The petrographic method as at present developed throws no light on the mineral character of soil material finer than silt, and as a consequence not only does it fail to give any information regarding the chemical character of that portion of the soil that probably is most reactive chemically, but may give rise to apparent discrepancies when the petrographic data are compared with the results of chemical analysis.



TABLE 3.—*Mineralogical analyses of soils for which chemical analyses are given in Table 1.*

[Petrographic examination by Wm. H. Fry.]

| Province and type.                     | Quartz. | Magnetite. | Orthoclase. | Microcline. | Biotite. | Muscovite. | Indeterminate micas. | Plagioclase. | Hornblende. | Epidote. | Titanite. | Cyanite. | Sillimanite. | Tourmaline. | Rutile. | Zircon. |
|----------------------------------------|---------|------------|-------------|-------------|----------|------------|----------------------|--------------|-------------|----------|-----------|----------|--------------|-------------|---------|---------|
| Great Plains province:                 |         |            |             |             |          |            |                      |              |             |          |           |          |              |             |         |         |
| Colorado sand, 0-14.....               | P.      | T.         | P.          | S.          | VS.      | VS.        |                      | P.           | S.          | T.       |           |          |              |             | T.      | ---     |
| 14-36.....                             | P.      | T.         | P.          | S.          | VS.      | VS.        |                      | P.           | S.          | T.       |           |          |              |             | VS.     | ---     |
| Oswego silt loam, 0-14.....            | P.      | T.         | P.          | T.          |          | VS.        |                      | VS.          | VS.         | VS.      | T.        |          |              |             | VS.     | ---     |
| 14-36.....                             | P.      | T.         | P.          |             |          | VS.        |                      | VS.          | VS.         | T.       |           |          |              |             | VS.     | T.      |
| Glacial and Loessial province:         |         |            |             |             |          |            |                      |              |             |          |           |          |              |             |         |         |
| Knox silt loam, 0-14.....              | P.      | T.         | S.          | T.          | T.       | S.         |                      | T.           | T.          | VS.      |           |          |              |             | VS.     | T.      |
| 14-36.....                             | P.      | T.         | S.          | T.          | T.       | S.         |                      | T.           | T.          | T.       | T.        |          |              |             | T.      | T.      |
| Memphis silt loam, 0-6.....            | P.      | T.         | S+          |             | S.       | VS.        |                      | VS.          | VS.         | VS.      | T.        |          |              |             | T.      | VS.     |
| 6-36.....                              | P.      | T.         | S.          |             | T.       | S+         |                      | VS.          | VS.         | T.       | T.        |          |              |             | T.      | VS.     |
| Memphis silt loam, 0-6.....            | P.      | T.         |             |             | VS.      | VS.        |                      |              | T.          | T.       | T.        |          |              |             | T.      | VS.     |
| 6-36.....                              | P.      | T.         | S.          |             | VS.      | S.         |                      | T.           | T.          | T.       |           |          |              |             | T.      | VS.     |
| River Flood Plains province:           |         |            |             |             |          |            |                      |              |             |          |           |          |              |             |         |         |
| Cahaba fine sandy loam, 0-12.....      | P.      | T.         | VS.         | T.          |          | VS.        |                      | T.           | T.          | T.       |           |          | T.           |             | T.      | T.      |
| 12-36.....                             | P.      | T.         | VS.         | T.          |          | VS.        |                      | T.           | T.          | T.       |           |          | T.           |             | T.      | T.      |
| Cahaba fine sandy loam, 0-12.....      | P.      | T.         | VS.         | T-          |          | T.         |                      | T.           | ?           | T-       |           |          |              |             | T.      | T.      |
| 12-36.....                             | P.      | T.         | VS.         |             |          | T.         |                      | T.           | T-          |          |           |          |              |             | T.      | T.      |
| Coastal Plain province:                |         |            |             |             |          |            |                      |              |             |          |           |          |              |             |         |         |
| Susquehanna clay, 0-4.....             | P.      | T+         | T.          |             |          | T.         |                      |              |             |          |           | T.       |              |             | VS.     | T.      |
| 4-36.....                              | P.      | T.         | T.          |             |          | T.         |                      |              |             |          |           |          |              |             | VS.     | T.      |
| Coxville fine sandy loam, 0-8.....     | P.      | T-         |             |             |          |            |                      |              |             |          |           | T.       |              |             | T.      | T.      |
| 8-16.....                              | P.      | T-         |             |             |          |            |                      |              |             |          |           | T.       |              |             | T.      | T.      |
| 16-36.....                             | P.      | T-         |             |             |          |            |                      |              |             |          |           |          |              |             | T.      | T.      |
| Norfolk sand, 0-8.....                 | P.      | T.         |             |             | T.       |            |                      |              |             |          |           |          |              |             | T.      | T.      |
| 8-36.....                              | P.      | T-         |             |             | T.       |            |                      |              |             |          |           | T.       |              |             | T.      | T.      |
| Orangeburg sand, 0-10.....             | P.      | T.         |             |             |          |            |                      |              |             |          |           |          | VS.          |             | T.      | T.      |
| 10-36.....                             | P.      | T-         |             |             |          |            |                      |              |             |          |           |          | T.           |             | T.      | T.      |
| Orangeburg sandy loam, 0-12.....       | P.      | T.         |             |             |          |            |                      |              |             |          |           |          |              |             | T.      | T.      |
| 12-36.....                             | P.      | T.         |             |             |          |            |                      |              |             |          |           |          |              |             | T.      | T.      |
| Greenville sandy loam, 0-10.....       | P.      | T.         | T.          |             |          |            |                      |              |             |          |           |          | T.           |             | T.      | T.      |
| 10-36.....                             | P.      | T.         |             |             |          |            |                      |              |             |          |           |          |              |             | T.      | T.      |
| Norfolk fine sandy loam, 0-10.....     | P.      | T-         |             |             |          |            |                      |              | T.          |          |           |          |              |             | T.      | T.      |
| 10-36.....                             | P.      | T-         |             |             |          |            |                      |              | T.          |          |           |          |              |             | T.      | T.      |
| Norfolk fine sandy loam, 0-16.....     | P.      | T-         |             |             |          |            | T.                   |              |             | T.       |           |          |              |             | VS.     | T.      |
| 16-36.....                             | P.      | T-         |             |             |          |            |                      |              |             |          |           |          |              |             | VS.     | T.      |
| Tifton fine sandy loam, 0-12.....      | P.      | T.         |             |             |          | T.         |                      |              | T.          |          |           |          |              |             | T.      | T.      |
| 12-36.....                             | P.      | T.         |             |             |          | T.         |                      |              | T.          |          | T.        |          |              |             | T.      | T.      |
| Ruston fine sandy loam, 0-6.....       | P.      | T.         | T.          |             |          | T.         |                      |              | T.          |          |           |          |              |             | T.      | T.      |
| 6-10.....                              | P.      | T.         | T.          |             |          | T.         |                      |              | T.          |          |           |          |              |             | T.      | T.      |
| Ruston fine sandy loam, 0-10.....      | P.      | T.         |             |             |          | T.         |                      |              |             |          |           |          |              |             | T.      | T.      |
| 10-36.....                             | P.      | T-         |             |             |          | T.         |                      |              |             |          |           |          |              |             | T.      | T.      |
| Susquehanna fine sandy loam, 0-12..... | P.      | T.         | T.          |             |          | T.         |                      |              | T.          |          |           |          |              |             | T.      | T.      |
| 12-36.....                             | P.      | T.         |             |             |          | VS.        |                      |              |             |          |           |          |              |             | T.      | T.      |
| Susquehanna fine sandy loam, 0-10..... | P.      | T.         | T.          |             |          | T.         |                      | T-           |             |          |           | T-       |              |             | T.      | T.      |
| 10-36.....                             | P.      | T-         | T+          |             |          |            |                      |              |             |          |           |          |              |             | T.      | T.      |
| Susquehanna fine sandy loam, 0-12..... | P.      | T.         | T.          |             |          |            |                      |              |             | T-       |           | T.       |              |             | T.      | T.      |
| 12-36.....                             | P.      | T.         |             |             |          |            | T.                   |              |             |          |           |          |              |             | T.      | T.      |
| Portsmouth fine sandy loam, 0-12.....  | P.      | T-         |             |             |          |            |                      |              |             |          |           |          |              |             | T.      | T.      |
| 12-36.....                             | P.      | T-         |             |             |          |            |                      |              |             |          |           |          | T.           |             | T.      | T.      |

In addition to the minerals mentioned in the table, a few others were sought but found once or twice only. These were: Garnet, a trace only, in the subsoil of Knox silt loam; apatite, a trace only, in the Cahaba very fine sandy loam; zoisite, a trace, found in soil of Knox silt loam, and the lower subsoil of Coxville fine sandy loam; cordierite indicated but not conclusive in subsoil of Greenville sandy loam; and chlorite, a trace, found in the subsoil of Susquehanna clay.

## DISCUSSION OF DATA.

Preliminary to any discussion of these data it should be observed that they are still too meager to warrant conclusions regarding many

phases of soil composition concerning which it is extremely desirable to reach conclusions, but with this limitation in mind it is thought that the following topics may be discussed from the point of view of chemical composition: Relation of soil to subsoil; extreme variation in composition; variation in soils of the same province; variation in soils of the same type; and the relation of the limit of error in analysis to quantities of constituents.

#### RELATION OF SOIL TO SUBSOIL.

It has been commonly observed that where there is a distinct subsoil, differing in color and texture from the surface soil, there may be a marked difference in the chemical composition of the two and that this difference is most marked in the content of silica, iron, and alumina. Usually it is found that the silica is higher in the surface soil and the iron and alumina in the subsoil.

The analyses presented here are in accord with this experience. Thirty-four locations are represented by soil and subsoil, and in all but two cases the silica is higher in the surface soil. The iron is higher in the subsoil in all but five cases, and the alumina in all but one.

Allowing a limit of error for all determinations of 0.05 per cent and regarding all figures that do not differ by more than 0.05 as equal, the relations of soil to subsoil in composition are summarized in Table 4.

In this table are stated the number of locations where soil and subsoil are the same in composition with regard to any constituent and the number of locations where they were found to differ by amounts of 0.05 to 0.5, 0.5 to 1, and more than 1 per cent.

TABLE 4.—*Comparison of soils and subsoils, as regards chemical composition.*

| Group.                                | SiO <sub>2</sub> . | Fe <sub>2</sub> O <sub>3</sub> . | Al <sub>2</sub> O <sub>3</sub> . | CaO. | MgO. | K <sub>2</sub> O. | Na <sub>2</sub> O. | P <sub>2</sub> O <sub>5</sub> . | SO <sub>3</sub> . |
|---------------------------------------|--------------------|----------------------------------|----------------------------------|------|------|-------------------|--------------------|---------------------------------|-------------------|
| Soil higher, more than 1 per cent.    | 28                 | 1                                |                                  |      |      |                   |                    |                                 |                   |
| Soil higher, 0.5 to 1 per cent.       | 3                  |                                  |                                  |      |      |                   |                    |                                 |                   |
| Soil higher, 0.05 to 0.5 per cent.    | 1                  | 4                                | 1                                | 8    | 3    | 5                 | 7                  | 3                               | 5                 |
| Soil and subsoil equal.               |                    |                                  |                                  | 19   | 7    | 12                | 22                 | 20                              | 24                |
| Subsoil higher, 0.05 to 0.5 per cent. |                    |                                  |                                  | 6    | 21   | 16                | 5                  | 2                               | 5                 |
| Subsoil higher, 0.5 to 1 per cent.    |                    | 11                               | 1                                | 1    | 3    | 1                 |                    |                                 |                   |
| Subsoil higher, more than 1 per cent. | 2                  | 18                               | 32                               |      |      |                   |                    |                                 |                   |

#### EXTREME VARIATION.

The soils analyzed represent a wide variation in kind of material from which they have been derived, processes of formation, topography, and present climatic conditions, and probably represent for some of the constituents nearly the extremes in composition of soils in this country.

The extremes in composition with regard to major constituents are as follows:

|                                               | Per cent.      |
|-----------------------------------------------|----------------|
| Silica, $\text{SiO}_2$ .....                  | 97.01 to 44.15 |
| Iron, $\text{Fe}_2\text{O}_3$ .....           | 16.23 to 0.33  |
| Alumina, $\text{Al}_2\text{O}_3$ .....        | 27.58 to 1.19  |
| Potash, $\text{K}_2\text{O}$ .....            | 4.07 to 0.02   |
| Soda, $\text{Na}_2\text{O}$ .....             | 2.06 to 0.01   |
| Lime, $\text{CaO}$ .....                      | 1.73 to 0.01   |
| Magnesia, $\text{MgO}$ .....                  | 1.93 to 0.01   |
| Phosphoric acid, $\text{P}_2\text{O}_5$ ..... | 0.22 to 0.03   |
| Sulphuric acid, $\text{SO}_3$ .....           | 0.34 to 0.02   |

There were 9 samples in which there were but traces (less than 0.01 per cent) of soda, 13 with but traces of magnesia, and 4 with but traces of lime.

In discussing the extreme variation shown in the samples analyzed the authors wish to avail themselves of general information they have regarding soil composition, based on partial analyses of other samples not here reported, and hold to the following opinion:

The maximum and minimum figures for silica, iron, and alumina stated above, while probably not the maximum or minimum of soils of the United States, are probably nearly so, and soils exceeding this maximum or not reaching this minimum in content of these constituents are not often met, except in the case of quartz sands on the one hand and muck soils on the other.

With regard to potash the same statement applies, although to a less extent. No soils have been encountered in these laboratories having less than 0.01 per cent  $\text{K}_2\text{O}$ , and while there are soils containing more than 5.0 per cent  $\text{K}_2\text{O}$  they are not common.

Less is known regarding the true maximum and minimum of soda content, for the reason that so few soils have been completely analyzed and there are few available data for this constituent. It is probable that in humid regions the maximum soda content of soils is considerably less than that of potash, and instances where but traces are present are not uncommon.

The results for lime and magnesia, while representing the minimum, are far from the maximum. Soils derived from calcareous material and as yet unleached may, of course, be very high in both lime and magnesia content, but even where there is little or no carbonate present the total content of lime and magnesia may each be above 5 per cent.

The figures for phosphoric acid do not represent the maximum or minimum. It is not uncommon to encounter soils containing 0.01 per cent, and soils containing as high as 0.8 per cent are often found, although generally confined to small areas.

The knowledge of the total sulphur content of soils is not extensive enough to make any general statement regarding the maximum and minimum content.



## VARIATION IN THE SAME PROVINCE.

The variation in composition of soils from the same soil province, soil and subsoil stated separately, is shown in Table 5:

TABLE 5. — *Variation in chemical composition of soils from the same province, soils and subsoils shown separately.*

| Province and sample.  | SiO <sub>2</sub> . | Fe <sub>2</sub> O <sub>3</sub> . | Al <sub>2</sub> O <sub>3</sub> . | CaO.      | MgO.      | K <sub>2</sub> O. | Na <sub>2</sub> O. | P <sub>2</sub> O <sub>5</sub> . | SO <sub>3</sub> . |
|-----------------------|--------------------|----------------------------------|----------------------------------|-----------|-----------|-------------------|--------------------|---------------------------------|-------------------|
|                       | Per cent.          | Per cent.                        | Per cent.                        | Per cent. | Per cent. | Per cent.         | Per cent.          | Per cent.                       | Per cent.         |
| Great Plains:         |                    |                                  |                                  |           |           |                   |                    |                                 |                   |
| Soil.....             | 78.85-71.38        | 3.63-2.72                        | 12.29- 9.68                      | 1.09-0.94 | 0.72-0.36 | 2.31-2.28         | 2.02-1.14          | 0.11-0.10                       | 0.12-0.07         |
| Subsoil.....          | 76.84-68.74        | 5.00-3.21                        | 14.45-11.09                      | 1.08-.88  | 1.12-.62  | 2.57-2.20         | 2.06-1.12          | .09-.08                         | .20-.18           |
| Glacial and Loessial: |                    |                                  |                                  |           |           |                   |                    |                                 |                   |
| Soil.....             | 81.13-65.08        | 5.67-2.92                        | 14.15- 8.48                      | 1.40-.27  | .83-.39   | 2.28-1.40         | 1.74-.52           | .22-.08                         | .17-.03           |
| Subsoil.....          | 75.95-71.43        | 5.58-3.99                        | 13.44-11.56                      | 1.19-.26  | 1.28-.39  | 2.22-1.60         | 1.74-.56           | .10-.10                         | .14-.03           |
| River Flood Plains:   |                    |                                  |                                  |           |           |                   |                    |                                 |                   |
| Soil.....             | 93.29-91.39        | .97-.78                          | 3.72- 2.45                       | .21-.15   | .09-.01   | .90-.45           | .12-.03            | .00-.03                         | .10-.06           |
| Subsoil.....          | 91.83-73.25        | 4.88-1.19                        | 13.19- 3.83                      | .15-.12   | .34-.09   | 1.08-.58          | .10-.05            | .05-.05                         | .13-.05           |
| Piedmont:             |                    |                                  |                                  |           |           |                   |                    |                                 |                   |
| Soil.....             | 88.57-66.49        | 7.43-1.55                        | 17.11- 5.76                      | 1.13-.08  | .69-.19   | 3.96-.62          | 1.53-.16           | .17-.05                         | .15-.04           |
| Subsoil.....          | 74.99-44.15        | 16.23-2.56                       | 27.58-10.90                      | 1.73-.21  | 1.06-.09  | 4.07-.61          | 1.54-.15           | .15-.05                         | .16-.06           |
| Coastal Plain:        |                    |                                  |                                  |           |           |                   |                    |                                 |                   |
| Soil.....             | 96.18-76.07        | 6.05-.41                         | 8.98- 1.37                       | .40-Tr.   | .32-Tr.   | .50-.05           | .29-Tr.            | .09-.04                         | .23-.02           |
| Subsoil.....          | 97.01-62.07        | 9.43-.33                         | 18.45- 1.19                      | .38-Tr.   | .67-Tr.   | .70-.02           | .14-Tr.            | .10-.03                         | .13-.03           |

It should be borne in mind in this connection that soil provinces may include soils derived from very different materials under very diverse climatic conditions, and the number of samples is far too small to permit any but the most general conclusions.

The least variation is found in the Great Plains and Glacial and Loessial provinces, and the greatest in the Piedmont Plateau, and wide variation in potash and soda is usually accompanied by wide variation in lime and magnesia. Phosphoric acid is remarkably uniform in each province, and in the Great Plains with a variation of 0.11 to 0.08, the River Flood Plains 0.06 to 0.05, and the Limestone Valleys 0.19 to 0.15 per cent the variation is not as great as might be obtained in duplicate analyses of the same sample. Therefore, so far as each of these provinces is represented by these samples, they may be said to be uniform in phosphoric-acid content.

# VARIATION IN SOILS OF THE SAME TYPE.

In this series of analyses few types are represented by more than one sample, but comparing in some cases sandy loams with fine sandy loams, the variation in major constituents in soils of the same or approximate textures is shown in Table 6:

TABLE 6.—*Variation in chemical composition of samples of the same type or of types of approximate textures.*

| Type.                                 | SiO <sub>2</sub> . | Fe <sub>2</sub> O <sub>3</sub> . | Al <sub>2</sub> O <sub>3</sub> . | CaO.             | MgO.             | K <sub>2</sub> O. | N <sub>2</sub> O. | P <sub>2</sub> O <sub>5</sub> . | SO <sub>2</sub> . |
|---------------------------------------|--------------------|----------------------------------|----------------------------------|------------------|------------------|-------------------|-------------------|---------------------------------|-------------------|
| Memphis silt loam:                    | <i>Per cent.</i>   | <i>Per cent.</i>                 | <i>Per cent.</i>                 | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i>  | <i>Per cent.</i>  | <i>Per cent.</i>                | <i>Per cent.</i>  |
| 1.....                                | 81.13              | 2.92                             | 8.52                             | 0.31             | 0.39             | 1.78              | 0.52              | 0.08                            | 0.03              |
| 2.....                                | 80.18              | 3.05                             | 8.48                             | .27              | .45              | 1.84              | .72               | .10                             | .03               |
| Cahaba fine and very fine sandy loam: |                    |                                  |                                  |                  |                  |                   |                   |                                 |                   |
| 1.....                                | 91.39              | .97                              | 3.72                             | .21              | .09              | .90               | .12               | .06                             | .06               |
| 2.....                                | 93.29              | .78                              | 2.45                             | .15              | .01              | .45               | .03               | .06                             | .10               |
| Norfolk sandy and fine sandy loam:    |                    |                                  |                                  |                  |                  |                   |                   |                                 |                   |
| 1.....                                | 94.50              | .83                              | 2.07                             | .39              | .09              | .10               | .11               | .06                             | .07               |
| 2.....                                | 95.54              | .62                              | 1.70                             | .06              | Trace.           | .06               | .18               | .05                             | .03               |
| 3.....                                | 92.87              | 1.17                             | 2.75                             | .03              | Trace.           | .05               | .01               | .04                             | .05               |
| Ruston fine sandy loam:               |                    |                                  |                                  |                  |                  |                   |                   |                                 |                   |
| 1.....                                | 95.51              | .68                              | 1.70                             | .12              | Trace.           | .16               | .04               | .04                             | .23               |
| 2.....                                | 90.22              | 1.52                             | 4.26                             | .06              | .01              | .12               | .14               | .05                             | .04               |
| Susquehanna fine sandy loam:          |                    |                                  |                                  |                  |                  |                   |                   |                                 |                   |
| 1.....                                | 90.90              | 3.02                             | 2.59                             | .11              | .09              | .28               | Trace.            | .04                             | .07               |
| 2.....                                | 91.57              | 3.00                             | 2.78                             | .04              | .03              | .10               | Trace.            | .09                             | .08               |
| 3.....                                | 91.17              | 1.31                             | 3.65                             | Trace.           | Trace.           | .12               | Trace.            | .04                             | .08               |

It will be observed that the two samples of Memphis silt loam taken a few miles apart in the same State are so nearly alike in composition that they could very well be considered duplicates of the same sample, and the same is true, perhaps to a less degree, of two samples of Susquehanna fine sandy loam, No. 1 and No. 2, taken in Texas and Mississippi, respectively.

On the other hand, samples No. 2 and No. 3 of Susquehanna fine sandy loam differ considerably in iron and alumina, and the samples

of Ruston fine sandy loam differ markedly in iron, alumina, and sulphur. Still further, on comparison of soils of different types, it is possible to choose two or more that agree quite as closely as any two of the same type. This is brought out in Table 7.

TABLE 7.—*Variation in the chemical composition of soils of the same texture but of different series.*

| Type.                        | SiO <sub>2</sub> . | Fe <sub>2</sub> O <sub>3</sub> . | Al <sub>2</sub> O <sub>3</sub> . | CaO.           | MgO.           | K <sub>2</sub> O. | Na <sub>2</sub> O. | P <sub>2</sub> O <sub>5</sub> . | SO <sub>3</sub> . |
|------------------------------|--------------------|----------------------------------|----------------------------------|----------------|----------------|-------------------|--------------------|---------------------------------|-------------------|
|                              | <i>Per ct.</i>     | <i>Per ct.</i>                   | <i>Per ct.</i>                   | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i>    | <i>Per ct.</i>     | <i>Per ct.</i>                  | <i>Per ct.</i>    |
| Norfolk fine sandy loam..... | 95.54              | 0.62                             | 1.70                             | 0.06           | Trace.         | 0.06              | 0.18               | 0.05                            | 0.03              |
| Ruston fine sandy loam.....  | 95.51              | .68                              | 1.70                             | .12            | Trace.         | .16               | .04                | .04                             | .23               |
| Tifton fine sandy loam.....  | 94.15              | .94                              | 1.67                             | .05            | Trace.         | .10               | Trace.             | .04                             | .06               |
| Portsmouth fine sandy loam.  | 94.85              | .41                              | 1.37                             | Trace.         | Trace.         | .06               | .06                | .05                             | .03               |
| Memphis silt loam.....       | 80.18              | 3.05                             | 8.48                             | .27            | 0.45           | 1.84              | .72                | .10                             | .03               |
| Decatur clay loam.....       | 79.35              | 4.44                             | 8.89                             | .63            | .39            | .67               | .24                | .18                             | .13               |
| Oswego silt loam.....        | 71.38              | 3.63                             | 12.29                            | 1.09           | .36            | 2.28              | 1.14               | .10                             | .18               |
| Hagerstown loam.....         | 70.99              | 4.23                             | 11.39                            | .93            | 1.08           | 2.71              | .82                | .19                             | .39               |

Probably no one has ever seriously contemplated classifying soils on the basis of their chemical composition alone, but it seems probable that soils that are alike in color, texture, relation of soil to subsoil, and formed by the same agencies, in other words, having such similar characteristics that they would be given the same type name by field observers, should have some chemical resemblance. The soils just compared, the analyses of which are more or less alike, are soils that because of characteristics other than texture have been given distinct type names; but how wide the variation of a single type may be in chemical composition, or whether some types should be separated into two or more because of chemical differences, or two or more types amalgamated because of chemical resemblances, is a matter for future investigation.

#### LIMIT OF ERROR IN ANALYTICAL WORK.

Earlier in the paper the authors stated what they considered the limit of error in the analytical work involved in the analyses here presented and discussed. It was stated that what was meant by limit of error was the allowable variation in results obtained from the same sample by two analysts familiar with the method used.

Several factors may contribute to this error: Lack of uniformity of sample, impure reagents, contamination from glassware or other utensils, and, finally, the error incident to the method, which may be of both a personal and chemical nature. All except the last may be nearly eliminated by care and blank determinations.

All analytical results are a compromise, usually arrived at by taking advantage of the solubility of compounds to be removed and the relative insolubility of the compound to be recovered and determined. No compound is absolutely insoluble, and when rela-



tively large quantities of easily soluble compounds have to be washed from a relatively small quantity of a nearly insoluble compound, an appreciable quantity of the latter may be lost before all of the former have been removed. As an example, in the fusion analysis of a soil after removal of the silica there remains an acid solution of all the bases with a large excess of sodium chloride. In the precipitation of calcium as calcium oxalate, it is necessary, of course, to remove this excess of chlorides, and calcium oxalate being slightly soluble, some is lost and may or may not be recovered later in the analysis. The personal factor of judgment comes in at this point and will explain many discrepancies.

The limits of error stated apply to analyses of soils of average composition by the fusion method. It is not meant, for instance, that the limit of error in all CaO determination is 0.10, for in the case of a dilute acid extract of a soil where the only excess of salts introduced is ammonium salts, the error allowed should be much smaller.

One of the reasons for drawing attention to this matter here is the practice in some quarters of publishing soil analyses in terms of pounds per acre. Such results are presumably based on an average of several analyses, but the variations of such analyses usually do not appear.

Assuming that an acre of soil 6 inches deep weighs 1,750,000 pounds, the limits of error stated when calculated to pounds per acre 6 inches deep would be as follows:

CaO limit 0.10 per cent or 1,750 pounds.

K<sub>2</sub>O limit 0.05 per cent or 875 pounds.

P<sub>2</sub>O<sub>5</sub> limit 0.04 per cent or 700 pounds.

Stated in another way it would appear as follows: Suppose a soil on analysis gave K<sub>2</sub>O, 0.50; CaO, 0.30; P<sub>2</sub>O<sub>5</sub>, 0.08, allowing the above limits of error, the composition might be:

|                                     | Per cent.      |
|-------------------------------------|----------------|
| K <sub>2</sub> O.....               | 0.525 or 0.475 |
| CaO.....                            | 0.35 or 0.25   |
| P <sub>2</sub> O <sub>5</sub> ..... | 0.10 or 0.06   |

Or in pounds per acre:

|                                     |                    |
|-------------------------------------|--------------------|
| K <sub>2</sub> O.....               | 9,187.5 or 8,312.5 |
| CaO.....                            | 6,125 or 4,375     |
| P <sub>2</sub> O <sub>5</sub> ..... | 1,750 or 1,050     |

It is quite plain then that too much significance should not be attached to differences of a few hundred pounds of any ingredient when the composition of a soil is expressed in pounds per acre, not because the actual presence or absence of such an amount might not have an effect, but because the statement based on chemical analysis may depart that much from the actual fact.

## SUMMARY.

In this paper there are presented the complete analyses of 45 samples of soil, representing four soil provinces. These, together with the analyses of 24 samples previously published representing also four provinces, are discussed from the points of view of extreme variation of all the samples, variation in composition within a soil province, variation of the same type, and the bearing of the limit of error in analysis on the interpretation of analytical data.

It is thought that the analyses discussed represent nearly the extremes in composition of soils in the regions in which the samples were taken. Marked resemblances in composition of soils from the same province are pointed out. It is shown that some samples of the same type differ considerably in chemical composition. It is also shown that some soils of different types may resemble each other in chemical composition as closely as different samples of the same type.

It is pointed out that the unavoidable error in analytical operations is in many cases of such magnitude that when analyses are stated in pounds per acre differences of several hundred pounds of some constituents are not significant.

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## UNITED STATES DEPARTMENT OF AGRICULTURE



## BULLETIN No. 552



Contribution from the Forest Service  
HENRY S. GRAVES, Forester

Washington, D. C.

PROFESSIONAL PAPER

July 9, 1917

THE SEASONING OF WOOD.<sup>1</sup>

By HAROLD S. BETTS, M. E., *in charge, Office of Industrial Investigations.*

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## IMPORTANCE OF PROPER SEASONING METHODS.

Practically all wood before being put to use is either seasoned in the air or dried in a kiln. The main objects of seasoning are to increase the durability of the wood in service, to prevent it from shrinking and checking, to increase its strength and stiffness, to prevent it from staining, and to decrease its weight. The sooner wood is seasoned after being cut the less is the chance that it will be injured by the insects, which attack unseasoned wood,<sup>2</sup> or decay before the time comes to use it. Wood that is to be treated with preservatives needs in nearly all cases to be seasoned as much as wood that is to be used in the natural state.

Wood has a complicated structure. The walls of the cells of which it is made up shrink and harden when moisture is removed from them, and unless timber that is to be air-seasoned is piled in the right way, or conditions in the dry kiln are maintained in accordance with certain well-defined physical laws, the material is likely to warp or check, or in some way to be damaged seriously. Until recently proper methods of seasoning received comparatively little attention from manufacturers, and large losses, especially among

<sup>1</sup> For assistance and suggestions given in connection with the preparation of this bulletin, the author is indebted to Mr. D. P. Sexton, of John B. Ransom & Co., Nashville, Tenn., and to Messrs. R. K. Helphentstine, jr., and N. de Witt Betts, of the Forest Service.

<sup>2</sup> The sapwood of seasoned hardwood is subject to attack and frequently to serious damage by powder-post insects. See Farmers' Bulletin 778, "Powder-Post Damage by Lyctus Beetles to Seasoned Hardwood," by A. D. Hopkins and T. E. Snyder, 1917.



woods that are difficult to dry, were the rule. Sometimes as much as 20 or 25 per cent of the seasoned lumber was rendered unfit for the use intended by defects which had their origin in the drying process. Since the quality of the finished product can be impaired seriously by wrong methods, the importance of right methods becomes apparent.

### FIBER SATURATION POINT AND SHRINKAGE.

Water exists in wood in two conditions:<sup>1</sup> (a) as free water contained in the cell cavities, and (b) as water absorbed in the cell walls. When wood contains just enough water to saturate the cell walls, it is said to be at the "fiber saturation point." Any water in excess of this which the wood may contain is in the form of free water in the

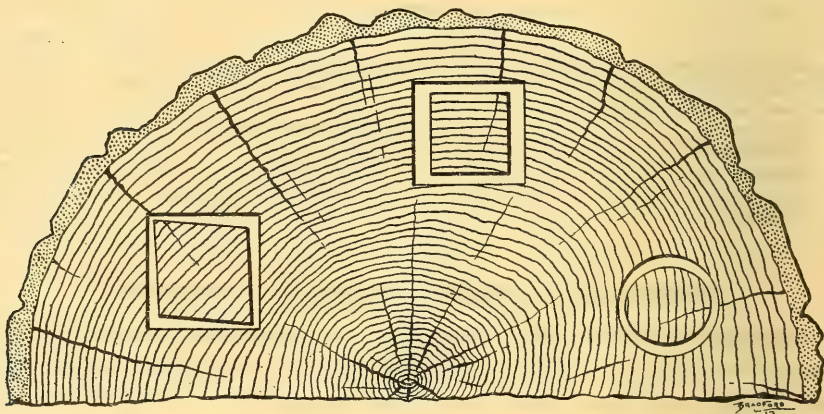


FIG. 1.—Shrinkage as affected by direction of annual rings; approximately twice as great tangentially as radially.

cell cavities. Removal of the free water has no apparent effect upon the properties of the wood except to reduce its weight, but as soon as any of the absorbed water is removed the wood begins to shrink. Since the free water is the first to be removed, shrinkage does not begin, as a general rule, until the fiber saturation point is reached. In the case of eucalyptus and some of the oaks, however, shrinkage begins above this point. For most woods the fiber saturation point corresponds with a moisture content of from 25 to 30 per cent of the dry weight of the wood. Figure 1 shows graphically the difference between tangential and radial shrinkage.

Shrinkage is due to the contraction of the cell walls, and sets up stresses which tend to cause the wood to check. As observed in a cross section of a piece of lumber, shrinkage in the tangential direction is about twice as great as in the radial direction; lengthwise of

<sup>1</sup> The term "sap" sometimes is used wrongly to mean the moisture in wood, and at other times to mean the sapwood. Sap is formed, mainly in the early spring, in the leaves from water rising from the roots through the sapwood. In the leaves this water is converted into true sap, which contains sugar and soluble gums. The sap descends through the bark and feeds the tissues in process of formation between the bark and the sapwood. The heartwood contains no sap.

the lumber it is very slight. Table I gives the green, air-dry, and kiln-dry weight per cubic foot of the principal commercial woods, and Table II gives the per cent of shrinkage from a green to an oven-dry condition.

TABLE I.—Average weights of various species of wood.

| Species and locality.                       | Weights (pounds per cubic foot). |                       |                     |
|---------------------------------------------|----------------------------------|-----------------------|---------------------|
|                                             | Kiln-dry. <sup>1</sup>           | Air-dry. <sup>2</sup> | Green. <sup>3</sup> |
| HARDWOODS.                                  |                                  |                       |                     |
| Alder, red, Snohomish County, Wash.....     | 27                               | 28                    | 46                  |
| Ash:                                        |                                  |                       |                     |
| Biltmore, Overton County, Tenn.....         | 38                               | 39                    | 45                  |
| Black—                                      |                                  |                       |                     |
| Ontonagon County, Mich.....                 | 34                               | 36                    | 53                  |
| Marathon County, Wis.....                   | 34                               | 35                    | 52                  |
| Blue, Bourbon County, Ky.....               | 39                               | 41                    | 46                  |
| Green—                                      |                                  |                       |                     |
| Richland Parish, La.....                    | 38                               | 39                    | 47                  |
| New Madrid County, Mo.....                  | 40                               | 42                    | 49                  |
| Oregon, Lane County, Oreg.....              | (4)                              | (4)                   | (4)                 |
| Pumpkin, New Madrid County, Mo.....         | 36                               | 37                    | 46                  |
| White—                                      |                                  |                       |                     |
| Stone County, Ark.....                      | 41                               | 42                    | 47                  |
| Oswego County, N. Y.....                    | 44                               | 46                    | 51                  |
| Pocahontas County, W. Va.....               | 37                               | 38                    | 46                  |
| Aspen:                                      |                                  |                       |                     |
| Rusk County, Wis.....                       | 26                               | 27                    | 47                  |
| Largetooth, Sauk County, Wis.....           | 26                               | 27                    | 43                  |
| Basswood:                                   |                                  |                       |                     |
| Potter County, Pa.....                      | 26                               | 27                    | 41                  |
| Marathon County, Wis.....                   | 24                               | 25                    | 41                  |
| Beech:                                      |                                  |                       |                     |
| Hendricks County, Ind.....                  | 43                               | 45                    | 56                  |
| Potter County, Pa.....                      | 41                               | 43                    | 54                  |
| Birch:                                      |                                  |                       |                     |
| Paper, Rusk County, Wis.....                | 37                               | 38                    | 51                  |
| Sweet, Potter County, Pa.....               | 45                               | 47                    | 59                  |
| Yellow—                                     |                                  |                       |                     |
| Potter County, Pa.....                      | 43                               | 45                    | 56                  |
| Marathon County, Wis.....                   | 43                               | 44                    | 59                  |
| Buckeye, yellow, Sevier County, Tenn.....   | 24                               | 25                    | 49                  |
| Buckthorn, cascara, Lane County, Oreg.....  | 35                               | 36                    | 50                  |
| Butternut:                                  |                                  |                       |                     |
| Sauk County, Wis.....                       | 25                               | 26                    | 45                  |
| Sevier County, Tenn.....                    | 27                               | 28                    | 47                  |
| Cherry:                                     |                                  |                       |                     |
| Black, Potter County, Pa.....               | 34                               | 36                    | 46                  |
| Wild red, Sevier County, Tenn.....          | 27                               | 28                    | 33                  |
| Chestnut:                                   |                                  |                       |                     |
| Baltimore County, Md.....                   | 29                               | 30                    | 53                  |
| Sevier County, Tenn.....                    | 29                               | 30                    | 56                  |
| Chinquapin, western, Lane County, Oreg..... | 31                               | 32                    | 61                  |
| Cottonwood:                                 |                                  |                       |                     |
| Pemiscot County, Mo.....                    | (4)                              | (4)                   | (4)                 |
| Black, Snohomish County, Wash.....          | 23                               | 24                    | 46                  |
| Cucumber tree, Sevier County, Tenn.....     | 33                               | 34                    | 50                  |
| Dogwood:                                    |                                  |                       |                     |
| Flowering, Sevier County, Tenn.....         | 52                               | 54                    | 65                  |
| Western, Lane County, Oreg.....             | 45                               | 47                    | 55                  |
| Elder, pale, Douglas County, Oreg.....      | 36                               | 37                    | 65                  |
| Elm:                                        |                                  |                       |                     |
| Cork—                                       |                                  |                       |                     |
| Marathon County, Wis.....                   | 43                               | 44                    | 53                  |
| Rusk County, Wis.....                       | 43                               | 45                    | 54                  |
| Slippery—                                   |                                  |                       |                     |
| Hendricks County, Ind.....                  | 42                               | 43                    | 53                  |
| Sauk County, Wis.....                       | 36                               | 37                    | 56                  |

<sup>1</sup> About 8 per cent moisture.

<sup>2</sup> About 12 or 15 per cent moisture. Average condition reached without artificial heating by material sheltered from precipitation, North Central States.

<sup>3</sup> Average green material.

<sup>4</sup> No figures available.

NOTE.—Any individual lot of lumber in the condition specified in the column headings would probably vary 5 per cent from the figures given with a possible variation of as much as 20 per cent. For example, young thrifty pines will have a high moisture content when freshly cut and will probably weigh 20 per cent above the average given.

TABLE I.—Average weights of various species of wood—Continued.

| Species and locality.                      | Weights (pounds per cubic foot). |          |        |
|--------------------------------------------|----------------------------------|----------|--------|
|                                            | Kiln-dry.                        | Air-dry. | Green. |
| <b>HARDWOODS—continued.</b>                |                                  |          |        |
| <b>Elm—Continued.</b>                      |                                  |          |        |
| White—                                     |                                  |          |        |
| Potter County, Pa.....                     | 35                               | 35       | 53     |
| Marathon County, Wis.....                  | 32                               | 33       | 45     |
| <b>Gum:</b>                                |                                  |          |        |
| Black, Sevier County, Tenn.....            | 35                               | 36       | 45     |
| Blue, Alameda County, Cal.....             | 52                               | 54       | 70     |
| <b>Red—</b>                                |                                  |          |        |
| New Madrid County, Mo.....                 | (1)                              | 35       | 46     |
| Pemiscot County, Mo.....                   | (1)                              | (1)      | (1)    |
| <b>Hackberry:</b>                          |                                  |          |        |
| Hendricks County, Ind.....                 | 38                               | 39       | 47     |
| Sauk County, Wis.....                      | 36                               | 38       | 51     |
| Haw, pear, Sauk County, Wis.....           | 47                               | 49       | 63     |
| <b>Hickory:</b>                            |                                  |          |        |
| Shellbark—                                 |                                  |          |        |
| Sardis, Miss.....                          | 47                               | 49       | 62     |
| Napoleon, Ohio.....                        | 55                               | 57       | 65     |
| Bitternut, Napoleon, Ohio.....             | 47                               | 49       | 64     |
| <b>Mockernut—</b>                          |                                  |          |        |
| Sardis, Miss.....                          | 47                               | 49       | 62     |
| Chester County, Pa.....                    | 53                               | 55       | 65     |
| Webster County, W. Va.....                 | (1)                              | (1)      | 62     |
| Nutmeg, Sardis, Miss.....                  | 42                               | 43       | 61     |
| <b>Pignut—</b>                             |                                  |          |        |
| Sardis, Miss.....                          | 48                               | 50       | 62     |
| Napoleon, Ohio.....                        | 51                               | 53       | 64     |
| Chester County, Pa.....                    | 52                               | 54       | 65     |
| Webster County, W. Va.....                 | 55                               | 57       | 63     |
| <b>Shagbark—</b>                           |                                  |          |        |
| Sardis, Miss.....                          | 47                               | 49       | 63     |
| Napoleon, Ohio.....                        | 51                               | 54       | 64     |
| Chester County, Pa.....                    | 45                               | 47       | 63     |
| Webster County, W. Va.....                 | 50                               | 52       | 65     |
| Water, Sardis, Miss.....                   | 44                               | 46       | 69     |
| Holly, American, Sevier County, Tenn.....  | 39                               | 40       | 57     |
| Hornbeam, Rusk County, Wis.....            | 35                               | 36       | 60     |
| <b>Laurel:</b>                             |                                  |          |        |
| California, Douglas County, Oreg.....      | (1)                              | (1)      | (1)    |
| Mountain, Sevier County, Tenn.....         | 47                               | 49       | 62     |
| <b>Locust:</b>                             |                                  |          |        |
| Black, Sevier County, Tenn.....            | 48                               | 49       | 58     |
| Honey, Hendricks County, Ind.....          | 49                               | 51       | 65     |
| <b>Madroña:</b>                            |                                  |          |        |
| Butte County, Cal.....                     | 42                               | 43       | 66     |
| Douglas County, Oreg.....                  | 46                               | 48       | 59     |
| <b>Maple:</b>                              |                                  |          |        |
| Broadleaf, Snohomish County, Wash.....     | 32                               | 34       | 47     |
| <b>Red—</b>                                |                                  |          |        |
| Marathon, Wis.....                         | 37                               | 38       | 54     |
| Potter County, Pa.....                     | 34                               | 36       | 49     |
| Silver, Sauk County, Wis.....              | 32                               | 34       | 46     |
| <b>Sugar—</b>                              |                                  |          |        |
| Hendricks County, Ind.....                 | 41                               | 43       | 54     |
| Potter County, Pa.....                     | 42                               | 44       | 58     |
| Marathon, County, Wis.....                 | 42                               | 44       | 56     |
| Magnolia (evergreen), Winn Parish, La..... | 34                               | 35       | 62     |
| <b>Oak:</b>                                |                                  |          |        |
| Bur, Sauk County, Wis.....                 | 43                               | 45       | 61     |
| California black—                          |                                  |          |        |
| Butte County, Cal.....                     | 37                               | 38       | 64     |
| Douglas County, Oreg.....                  | (1)                              | (1)      | (1)    |
| Canyon live, Butte County, Cal.....        | 54                               | 56       | 71     |
| Chestnut, Sevier County, Tenn.....         | 45                               | 46       | 62     |
| Cow, Winn Parish, La.....                  | 48                               | 50       | 65     |
| Laurel, Winn Parish, La.....               | 45                               | 47       | 65     |
| Pacific post, Douglas County, Oreg.....    | (1)                              | (1)      | (1)    |
| <b>Post—</b>                               |                                  |          |        |
| Stone County, Ark.....                     | 46                               | 47       | 60     |
| Winn Parish, La.....                       | 47                               | 49       | 66     |
| <b>Red—</b>                                |                                  |          |        |
| Stone County, Ark.....                     | 43                               | 45       | 65     |
| Hendricks County, Ind.....                 | 42                               | 44       | 64     |
| Richland Parish, La.....                   | 48                               | 50       | 67     |
| Sevier County, Tenn.....                   | 41                               | 42       | 61     |

1 No figures available.



TABLE I.—Average weights of various species of wood—Continued.

| Species and locality.                          | Weights (pounds per cubic foot). |          |        |
|------------------------------------------------|----------------------------------|----------|--------|
|                                                | Kiln-dry.                        | Air-dry. | Green. |
| HARDWOODS—continued.                           |                                  |          |        |
| Oak—Continued.                                 |                                  |          |        |
| Spanish—                                       |                                  |          |        |
| Lowland, Winn Parish, La. ....                 | 47                               | 49       | 67     |
| Highland, Winn Parish, La. ....                | 40                               | 42       | 62     |
| Swamp white, Hendricks County, Ind. ....       | 50                               | 52       | 69     |
| Tanbark, Willits, Cal. ....                    | 43                               | 44       | 66     |
| Water, Winn Parish, La. ....                   | 43                               | 45       | 63     |
| White—                                         |                                  |          |        |
| Stone County, Ark. ....                        | 46                               | 48       | 59     |
| Hendricks County, Ind. ....                    | 46                               | 47       | 61     |
| Richland Parish, La. ....                      | 46                               | 48       | 67     |
| Winn Parish, La. ....                          | 46                               | 47       | 63     |
| Willow, Winn Parish, La. ....                  | 45                               | 46       | 76     |
| Yellow—                                        |                                  |          |        |
| Stone County, Ark. ....                        | 43                               | 45       | 63     |
| Marathon County, Wis. ....                     | 40                               | 42       | 62     |
| Osage orange, Morgan County, Ind. ....         | 54                               | 56       | 62     |
| Poplar, yellow, Sevier County, Tenn. ....      | 27                               | 28       | 38     |
| Rhododendron, great, Sevier County, Tenn. .... | 39                               | 40       | 62     |
| Sassafras, Sevier County, Tenn. ....           | 31                               | 32       | 49     |
| Serviceberry, Sevier County, Tenn. ....        | 52                               | 54       | 61     |
| Silverbell tree, Sevier County, Tenn. ....     | 31                               | 32       | 44     |
| Sourwood, Sevier County, Tenn. ....            | 39                               | 40       | 53     |
| Sumach, staghorn, Sauk County, Wis. ....       | 32                               | 34       | 41     |
| Sycamore:                                      |                                  |          |        |
| Hendricks County, Ind. ....                    | 34                               | 35       | 51     |
| Sevier County, Tenn. ....                      | 35                               | 36       | 53     |
| Tupelo, St. John the Baptist Parish, La. ....  | 35                               | 37       | 66     |
| Umbrella, Fraser, Sevier County, Tenn. ....    | 30                               | 31       | 47     |
| Walnut, black, Kentucky. ....                  | 41                               | 44       | 58     |
| Willow:                                        |                                  |          |        |
| Western black, Douglas County, Oreg. ....      | 30                               | 31       | 51     |
| Black, Sauk County, Wis. ....                  | 25                               | 26       | 51     |
| Witch hazel, Sevier County, Tenn. ....         | 45                               | 46       | 59     |
| CONIFERS.                                      |                                  |          |        |
| Cedar.                                         |                                  |          |        |
| Incense—                                       |                                  |          |        |
| Lane County, Oreg. ....                        | (1)                              | (1)      | (1)    |
| Weed, Cal. ....                                | (1)                              | (1)      | 41     |
| Port Orford, Douglas County, Oreg. ....        | 30                               | 31       | 39     |
| Western red—                                   |                                  |          |        |
| Missoula County, Mont. ....                    | 21                               | 22       | 24     |
| Snohomish County, Wash. ....                   | 23                               | 24       | 30     |
| White, Shawano County, Wis. ....               | 21                               | 21       | 28     |
| Cypress:                                       |                                  |          |        |
| Bald, St. John the Baptist Parish, La. ....    | 33                               | 34       | 51     |
| Yellow, Lane County, Oreg. ....                | (1)                              | (1)      | (1)    |
| Douglas fir:                                   |                                  |          |        |
| Plumas County, Cal. ....                       | 30                               | 31       | 40     |
| Humboldt County, Cal. ....                     | (1)                              | (1)      | (1)    |
| Johnson County, Wyo. ....                      | 31                               | 32       | 34     |
| Lane County, Oreg. ....                        | 35                               | 36       | 39     |
| Chehalis County, Wash. ....                    | 31                               | 32       | 36     |
| Lewis County, Wash. ....                       | 35                               | 37       | 41     |
| Washington and Oregon. ....                    | (1)                              | (1)      | 37     |
| Missoula County, Mont. ....                    | (1)                              | (1)      | (1)    |
| Fir:                                           |                                  |          |        |
| Amabilis—                                      |                                  |          |        |
| Dee, Oreg. ....                                | (1)                              | (1)      | 52     |
| Snohomish County, Wash. ....                   | 26                               | 27       | 36     |
| Alpine, Grand County, Colo. ....               | 22                               | 23       | 28     |
| Balsam, Rusk County, Wis. ....                 | 24                               | 25       | 45     |
| Grand—                                         |                                  |          |        |
| Missoula County, Mont. ....                    | 28                               | 29       | 37     |
| Douglas County, Oreg. ....                     | (1)                              | (1)      | (1)    |
| Noble, Multnomah County, Oreg. ....            | 27                               | 28       | 31     |
| White, Madera County, Cal. ....                | 25                               | 26       | 56     |
| Hemlock:                                       |                                  |          |        |
| Sevier County, Tenn. ....                      | 31                               | 32       | 48     |
| Marathon County, Wis. ....                     | 24                               | 25       | 49     |
| Mountain, Missoula County, Mont. ....          | 30                               | 32       | 45     |
| Western—                                       |                                  |          |        |
| Chehalis County, Wash. ....                    | (1)                              | (1)      | (1)    |
| Grays Harbor and Buckley, Wash. ....           | 30                               | 31       | 40     |

1 No figures available.

TABLE I.—Average weights of various species of wood—Continued.

| Species and locality.                     | Weights (pounds per cubic foot). |          |        |
|-------------------------------------------|----------------------------------|----------|--------|
|                                           | Kiln-dry.                        | Air-dry. | Green. |
| CONIFERS—continued.                       |                                  |          |        |
| Larch, western:                           |                                  |          |        |
| Missoula County, Mont.....                | 37                               | 39       | 51     |
| Stevens County, Wash.....                 | 33                               | 34       | 42     |
| Pine:                                     |                                  |          |        |
| Jack, Barron County, Wis.....             | 29                               | 30       | 50     |
| Jeffrey, Plumas County, Cal.....          | 27                               | 28       | 47     |
| Loblolly, Nassau County, Fla.....         | 37                               | 39       | 54     |
| Lodgepole—                                |                                  |          |        |
| Grand County, Colo.....                   | 27                               | 28       | 33     |
| Gallatin County, Mont.....                | 27                               | 28       | 47     |
| Granite County, Mont.....                 | 29                               | 30       | 41     |
| Jefferson County, Mont.....               | 28                               | 29       | 39     |
| Johnson County, Wyo.....                  | 27                               | 28       | 37     |
| Longleaf—                                 |                                  |          |        |
| Nassau County, Fla.....                   | 42                               | 44       | 51     |
| Bogalusa, La.....                         | (1)                              | (1)      | (1)    |
| Lake Charles, La.....                     | 42                               | 43       | 45     |
| Tangipahoa Parish, La.....                | 39                               | 41       | 54     |
| Hattiesburg, Miss.....                    | 38                               | 40       | 42     |
| Pitch, Sevier County, Tenn.....           | 35                               | 36       | 54     |
| Pond, Nassau County, Fla.....             | 38                               | 40       | 49     |
| Norway, Shawano County, Wis.....          | 32                               | 34       | 42     |
| Shortleaf—                                |                                  |          |        |
| Malvern, Ark.....                         | 35                               | 36       | 45     |
| Bogalusa, La.....                         | (1)                              | (1)      | (1)    |
| Slash, Nassau County, Fla.....            | 43                               | 45       | 53     |
| Sugar, Madera County, Cal.....            | 26                               | 27       | 50     |
| Table-mountain, Sevier County, Tenn.....  | 36                               | 37       | 54     |
| Western white, Missoula County, Mont..... | 29                               | 30       | 39     |
| Western yellow—                           |                                  |          |        |
| Coconino County, Ariz.....                | 25                               | 26       | 44     |
| Madera County, Cal.....                   | 28                               | 29       | 53     |
| Douglas County, Colo.....                 | 28                               | 29       | 49     |
| Missoula County, Mont.....                | 27                               | 28       | 51     |
| White, Shawano County, Wis.....           | 26                               | 27       | 39     |
| Redwood:                                  |                                  |          |        |
| Humboldt County, Cal.....                 | 23                               | 24       | 38     |
| Mendocino County, Cal.....                | 26                               | 27       | 39     |
| Spruce:                                   |                                  |          |        |
| Engelmann—                                |                                  |          |        |
| San Miguel County, Colo.....              | 22                               | 23       | 48     |
| Grand County, Colo.....                   | 24                               | 25       | 30     |
| Red—                                      |                                  |          |        |
| Coos County, N. H.....                    | 28                               | 29       | 32     |
| Sevier County, Tenn.....                  | 27                               | 28       | 35     |
| Sitka, Chehalis County, Wash.....         | (1)                              | (1)      | (1)    |
| White—                                    |                                  |          |        |
| Coos County, N. H.....                    | 25                               | 26       | 28     |
| Rusk County, Wis.....                     | 29                               | 30       | 35     |
| Tamarack, Shawano County, Wis.....        | 37                               | 38       | 47     |
| Yew, western, Snohomish County, Wash..... | 43                               | 45       | 54     |

<sup>1</sup> No figures available.

TABLE II.—Average shrinkage of various species of wood.

| Species and locality.                        | Shrinkage from a green to an oven-dry condition (per cent of dimensions when green). |                                                                                   |                                                                                   |
|----------------------------------------------|--------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
|                                              | Volume.                                                                              | Radial.                                                                           | Tangential.                                                                       |
|                                              |     |  |  |
| <b>HARDWOODS.</b>                            |                                                                                      |                                                                                   |                                                                                   |
| Alder, red, Snohomish County, Wash. ....     | 12.6                                                                                 | 4.4                                                                               | 7.3                                                                               |
| Ash:                                         |                                                                                      |                                                                                   |                                                                                   |
| Biltmore, Overton County, Tenn. ....         | 12.6                                                                                 | 4.2                                                                               | 6.9                                                                               |
| Black—                                       |                                                                                      |                                                                                   |                                                                                   |
| Ontonagon, Mich. ....                        | 15.2                                                                                 | 5.0                                                                               | 7.8                                                                               |
| Marathon County, Wis. ....                   | (1)                                                                                  | (1)                                                                               | (1)                                                                               |
| Blue, Bourbon County, Ky. ....               | 11.7                                                                                 | 3.9                                                                               | 6.5                                                                               |
| Green—                                       |                                                                                      |                                                                                   |                                                                                   |
| Richland Parish, La. ....                    | 11.7                                                                                 | (1)                                                                               | (1)                                                                               |
| New Madrid County, Mo. ....                  | 13.3                                                                                 | 4.6                                                                               | 7.1                                                                               |
| Oregon, Lane County, Oreg. ....              | (1)                                                                                  | (1)                                                                               | (1)                                                                               |
| Pumpkin, New Madrid County, Mo. ....         | 12.0                                                                                 | 3.7                                                                               | 6.3                                                                               |
| White—                                       |                                                                                      |                                                                                   |                                                                                   |
| Stone County, Ark. ....                      | 12.6                                                                                 | 4.3                                                                               | 6.4                                                                               |
| Oswego County, N. Y. ....                    | 14.0                                                                                 | 5.3                                                                               | 8.7                                                                               |
| Pocahontas County, W. Va. ....               | 12.6                                                                                 | 4.1                                                                               | 6.6                                                                               |
| Aspen:                                       |                                                                                      |                                                                                   |                                                                                   |
| Rusk County, Wis. ....                       | 11.1                                                                                 | 3.3                                                                               | 6.9                                                                               |
| Largetooth, Sauk County, Wis. ....           | 11.6                                                                                 | 3.1                                                                               | 7.9                                                                               |
| Basswood:                                    |                                                                                      |                                                                                   |                                                                                   |
| Potter County, Pa. ....                      | 16.5                                                                                 | 6.8                                                                               | 9.9                                                                               |
| Marathon County, Wis. ....                   | 14.5                                                                                 | 6.2                                                                               | 8.4                                                                               |
| Beech:                                       |                                                                                      |                                                                                   |                                                                                   |
| Hendricks County, Ind. ....                  | 16.5                                                                                 | 4.6                                                                               | 10.5                                                                              |
| Potter County, Pa. ....                      | 15.8                                                                                 | 5.1                                                                               | 10.6                                                                              |
| Birch:                                       |                                                                                      |                                                                                   |                                                                                   |
| Paper, Rusk County, Wis. ....                | 16.3                                                                                 | 6.6                                                                               | 8.8                                                                               |
| Sweet, Potter County ....                    | 15.0                                                                                 | 6.3                                                                               | 7.6                                                                               |
| Yellow—                                      |                                                                                      |                                                                                   |                                                                                   |
| Potter County, Pa. ....                      | 16.7                                                                                 | 6.9                                                                               | 8.9                                                                               |
| Marathon County, Wis. ....                   | 17.0                                                                                 | 7.9                                                                               | 9.0                                                                               |
| Buckeye, yellow, Sevier County, Tenn. ....   | 12.0                                                                                 | 3.5                                                                               | 2.8                                                                               |
| Buckthorn, cascara, Lane County, Oreg. ....  | 7.6                                                                                  | 3.2                                                                               | 4.6                                                                               |
| Butternut:                                   |                                                                                      |                                                                                   |                                                                                   |
| Sauk County, Wis. ....                       | 9.4                                                                                  | 3.6                                                                               | 5.7                                                                               |
| Sevier County, Tenn. ....                    | 11.1                                                                                 | 3.0                                                                               | 6.5                                                                               |
| Cherry:                                      |                                                                                      |                                                                                   |                                                                                   |
| Black, Potter County, Pa. ....               | 11.5                                                                                 | 3.7                                                                               | 7.1                                                                               |
| Wild red, Sevier County, Tenn. ....          | 12.8                                                                                 | 2.8                                                                               | 10.3                                                                              |
| Chestnut:                                    |                                                                                      |                                                                                   |                                                                                   |
| Baltimore County, Md. ....                   | 10.4                                                                                 | 3.3                                                                               | 6.6                                                                               |
| Sevier County, Tenn. ....                    | 18.9                                                                                 | 3.4                                                                               | 6.8                                                                               |
| Chinquapin, western, Lane County, Oreg. .... | 13.2                                                                                 | 4.6                                                                               | 7.4                                                                               |
| Cottonwood:                                  |                                                                                      |                                                                                   |                                                                                   |
| Pemiscot County, Mo. ....                    | (1)                                                                                  | (1)                                                                               | (1)                                                                               |
| Black, Snohomish County, Wash. ....          | 12.4                                                                                 | 3.6                                                                               | 8.6                                                                               |
| Cucumber tree, Sevier County, Tenn. ....     | 13.6                                                                                 | 5.2                                                                               | 8.8                                                                               |
| Dogwood:                                     |                                                                                      |                                                                                   |                                                                                   |
| Flowering, Sevier County, Tenn. ....         | 19.9                                                                                 | 7.1                                                                               | 11.3                                                                              |
| Western, Lane County, Oreg. ....             | 17.2                                                                                 | 6.4                                                                               | 9.6                                                                               |
| Elder, pale, Douglas County, Oreg. ....      | 15.6                                                                                 | 4.4                                                                               | 9.0                                                                               |
| Elm:                                         |                                                                                      |                                                                                   |                                                                                   |
| Cork—                                        |                                                                                      |                                                                                   |                                                                                   |
| Marathon County, Wis. ....                   | (1)                                                                                  | (1)                                                                               | (1)                                                                               |
| Rusk County, Wis. ....                       | 14.1                                                                                 | 4.8                                                                               | 8.1                                                                               |
| Slippery—                                    |                                                                                      |                                                                                   |                                                                                   |
| Hendricks County, Ind. ....                  | 15.5                                                                                 | 5.1                                                                               | 9.9                                                                               |
| Sauk County, Wis. ....                       | 13.4                                                                                 | 4.9                                                                               | 8.7                                                                               |
| White—                                       |                                                                                      |                                                                                   |                                                                                   |
| Potter County, Pa. ....                      | 14.4                                                                                 | 4.2                                                                               | 9.5                                                                               |
| Marathon County, Wis. ....                   | (1)                                                                                  | (1)                                                                               | (1)                                                                               |

1 No figures available.

NOTE.—Oven-dry means entirely free from water. The shrinkage from a green to a kiln-dry condition (8 per cent moisture) is generally about 75 per cent of the shrinkage to an oven-dry condition. The shrinkage from a green to an air-dry condition (12 to 15 per cent moisture) is generally about 50 per cent of the shrinkage to an oven-dry condition.



TABLE II.—Average shrinkage of various species of wood—Continued.

| Species and locality.                  | Shrinkage from a green to an oven-dry condition (per cent of dimensions when green).         |                                                                                              |                                                                                                   |
|----------------------------------------|----------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
|                                        | Volume.<br> | Radial.<br> | Tangential.<br> |
| HARDWOODS—continued.                   |                                                                                              |                                                                                              |                                                                                                   |
| Gum:                                   |                                                                                              |                                                                                              |                                                                                                   |
| Black, Sevier County, Tenn.            | 13.9                                                                                         | 4.4                                                                                          | 7.7                                                                                               |
| Blue, Alameda County, Cal.             | 22.5                                                                                         | 7.6                                                                                          | 15.3                                                                                              |
| Red—                                   |                                                                                              |                                                                                              |                                                                                                   |
| New Madrid County, Mo.                 | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                                  |
| Pemiscot County, Mo.                   | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                                  |
| Hackberry:                             |                                                                                              |                                                                                              |                                                                                                   |
| Hendricks County, Ind.                 | 14.0                                                                                         | 4.2                                                                                          | 8.9                                                                                               |
| Sauk County, Wis.                      | 13.8                                                                                         | 4.9                                                                                          | 8.9                                                                                               |
| Haw, pear, Sauk County, Wis.           | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                                  |
| Hickory:                               |                                                                                              |                                                                                              |                                                                                                   |
| Shellbark—                             |                                                                                              |                                                                                              |                                                                                                   |
| Sardis, Miss.                          | 17.6                                                                                         | 7.4                                                                                          | 11.2                                                                                              |
| Napoleon, Ohio.                        | 20.9                                                                                         | 7.9                                                                                          | 14.2                                                                                              |
| Bitternut, Napoleon, Ohio.             | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                                  |
| Mockernut—                             |                                                                                              |                                                                                              |                                                                                                   |
| Sardis, Miss.                          | 16.5                                                                                         | 6.9                                                                                          | 11.4                                                                                              |
| Chester County, Pa.                    | 18.9                                                                                         | 8.4                                                                                          | 11.4                                                                                              |
| Webster County, W. Va.                 | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                                  |
| Nutmeg, Sardis, Miss.                  | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                                  |
| Pignut—                                |                                                                                              |                                                                                              |                                                                                                   |
| Sardis, Miss.                          | 15.0                                                                                         | 5.6                                                                                          | 9.8                                                                                               |
| Napoleon, Ohio.                        | 15.3                                                                                         | 6.3                                                                                          | 9.5                                                                                               |
| Chester County, Pa.                    | 16.9                                                                                         | 6.8                                                                                          | 10.9                                                                                              |
| Webster County, W. Va.                 | 21.2                                                                                         | 8.5                                                                                          | 13.8                                                                                              |
| Shagbark—                              |                                                                                              |                                                                                              |                                                                                                   |
| Sardis, Miss.                          | 16.0                                                                                         | 6.5                                                                                          | 10.2                                                                                              |
| Napoleon, Ohio.                        | 18.4                                                                                         | 7.9                                                                                          | 11.4                                                                                              |
| Chester County, Pa.                    | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                                  |
| Webster County, W. Va.                 | 15.5                                                                                         | 6.5                                                                                          | 9.7                                                                                               |
| Water, Sardis, Miss.                   | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                                  |
| Holly, American, Sevier County, Tenn.  | 16.2                                                                                         | 4.5                                                                                          | 9.5                                                                                               |
| Hornbeam, Rusk County, Wis.            | ( <sup>1</sup> )                                                                             | 8.2                                                                                          | 9.6                                                                                               |
| Laurel:                                |                                                                                              |                                                                                              |                                                                                                   |
| California, Douglas County, Oreg.      | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                                  |
| Mountain, Sevier County, Tenn.         | 14.4                                                                                         | 5.6                                                                                          | 8.8                                                                                               |
| Locust:                                |                                                                                              |                                                                                              |                                                                                                   |
| Black, Sevier County, Tenn.            | 9.8                                                                                          | 4.4                                                                                          | 6.9                                                                                               |
| Honey, Hendricks County, Ind.          | 8.6                                                                                          | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                                  |
| Madroña:                               |                                                                                              |                                                                                              |                                                                                                   |
| Butte County, Cal.                     | 16.2                                                                                         | 5.1                                                                                          | 11.7                                                                                              |
| Douglas County, Oreg.                  | 17.6                                                                                         | 5.5                                                                                          | 11.9                                                                                              |
| Maple:                                 |                                                                                              |                                                                                              |                                                                                                   |
| Broadleaf, Snohomish County, Wash.     | 11.6                                                                                         | 3.7                                                                                          | 7.1                                                                                               |
| Red—                                   |                                                                                              |                                                                                              |                                                                                                   |
| Marathon County, Wis.                  | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                                  |
| Potter County, Pa.                     | 12.5                                                                                         | 3.8                                                                                          | 8.1                                                                                               |
| Silver, Sauk County, Wis.              | 12.0                                                                                         | 3.0                                                                                          | 7.2                                                                                               |
| Sugar—                                 |                                                                                              |                                                                                              |                                                                                                   |
| Hendricks County, Ind.                 | 14.3                                                                                         | 4.9                                                                                          | 9.1                                                                                               |
| Potter County, Pa.                     | 14.7                                                                                         | 4.8                                                                                          | 9.2                                                                                               |
| Marathon County, Wis.                  | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                                  |
| Magnolia (evergreen), Winn Parish, La. | 12.3                                                                                         | 5.4                                                                                          | 6.6                                                                                               |
| Oak, bur, Sauk County, Wis.            | 12.7                                                                                         | 4.4                                                                                          | 8.8                                                                                               |
| California black—                      |                                                                                              |                                                                                              |                                                                                                   |
| Butte County, Cal.                     | 13.6                                                                                         | 4.1                                                                                          | 6.4                                                                                               |
| Douglas County, Oreg.                  | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                                  |
| Canyon live, Butte County, Cal.        | 16.2                                                                                         | 8.0                                                                                          | 14.3                                                                                              |
| Chestnut, Sevier County, Tenn.         | 16.7                                                                                         | 5.5                                                                                          | 9.7                                                                                               |
| Cow, Winn Parish, La.                  | 19.4                                                                                         | 5.9                                                                                          | 9.2                                                                                               |
| Laurel, Winn Parish, La.               | 19.0                                                                                         | 3.9                                                                                          | 9.5                                                                                               |
| Pacific post, Douglas County, Oreg.    | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                             | ( <sup>1</sup> )                                                                                  |
| Post—                                  |                                                                                              |                                                                                              |                                                                                                   |
| Stone County, Ark.                     | 16.0                                                                                         | 5.7                                                                                          | 10.6                                                                                              |
| Winn Parish, La.                       | 16.5                                                                                         | 5.2                                                                                          | 8.9                                                                                               |

<sup>1</sup> No figures available.

TABLE II.—Average shrinkage of various species of wood—Continued.

| Species and locality.                     | Shrinkage from a green to an oven-dry condition (per cent of dimensions when green).         |                                                                                              |                                                                                                  |
|-------------------------------------------|----------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
|                                           | Volume.<br> | Radial.<br> | Tangential.<br> |
| <b>HARDWOODS—continued.</b>               |                                                                                              |                                                                                              |                                                                                                  |
| Oak—Continued.                            |                                                                                              |                                                                                              |                                                                                                  |
| Red—                                      |                                                                                              |                                                                                              |                                                                                                  |
| Stone County, Ark.                        | 14.5                                                                                         | 4.2                                                                                          | 8.3                                                                                              |
| Hendricks County, Ind.                    | 13.1                                                                                         | 3.7                                                                                          | 8.3                                                                                              |
| Richland Parish, La.                      | (1)                                                                                          | (1)                                                                                          | (1)                                                                                              |
| Sevier County, Tenn.                      | 15.3                                                                                         | 3.7                                                                                          | 8.3                                                                                              |
| Spanish—                                  |                                                                                              |                                                                                              |                                                                                                  |
| Lowland, Winn Parish, La.                 | 16.4                                                                                         | 5.2                                                                                          | 10.8                                                                                             |
| Highland, Winn Parish, La.                | 16.3                                                                                         | 4.5                                                                                          | 8.7                                                                                              |
| Swamp white, Hendricks County, Ind.       | 17.7                                                                                         | 5.5                                                                                          | 10.0                                                                                             |
| Tanbark, Willits, Cal.                    | (1)                                                                                          | (1)                                                                                          | (1)                                                                                              |
| Water, Winn Parish, La.                   | 16.4                                                                                         | 4.2                                                                                          | 9.3                                                                                              |
| White—                                    |                                                                                              |                                                                                              |                                                                                                  |
| Stone County, Ark.                        | 15.8                                                                                         | 6.2                                                                                          | 8.3                                                                                              |
| Hendricks County, Ind.                    | 14.3                                                                                         | 4.9                                                                                          | 9.0                                                                                              |
| Richland Parish, La.                      | 16.0                                                                                         | 4.8                                                                                          | 9.2                                                                                              |
| Winn Parish, La.                          | 16.9                                                                                         | 5.4                                                                                          | 9.5                                                                                              |
| Willow, Winn Parish, La.                  | 18.9                                                                                         | 5.0                                                                                          | 9.6                                                                                              |
| Yellow—                                   |                                                                                              |                                                                                              |                                                                                                  |
| Stone County, Ark.                        | 14.2                                                                                         | 4.5                                                                                          | 9.7                                                                                              |
| Marathon County, Wis.                     | (1)                                                                                          | (1)                                                                                          | (1)                                                                                              |
| Osage orange, Morgan County, Ind.         | 8.9                                                                                          | (1)                                                                                          | (1)                                                                                              |
| Poplar, yellow, Sevier County, Tenn.      | 11.4                                                                                         | 4.1                                                                                          | 6.9                                                                                              |
| Rhododendron, great, Sevier County, Tenn. | 16.2                                                                                         | 6.3                                                                                          | 8.7                                                                                              |
| Sassafras, Sevier County, Tenn.           | 10.3                                                                                         | 4.0                                                                                          | 6.2                                                                                              |
| Serviceberry, Sevier County, Tenn.        | 18.7                                                                                         | 6.7                                                                                          | 10.8                                                                                             |
| Silverbell tree, Sevier County, Tenn.     | 12.6                                                                                         | 3.8                                                                                          | 7.6                                                                                              |
| Sourwood, Sevier County, Tenn.            | 15.2                                                                                         | 6.3                                                                                          | 8.9                                                                                              |
| Sumach, staghorn, Sauk County, Wis.       | (1)                                                                                          | (1)                                                                                          | (1)                                                                                              |
| Sycamore:                                 |                                                                                              |                                                                                              |                                                                                                  |
| Hendricks County, Ind.                    | 13.5                                                                                         | 5.0                                                                                          | 7.3                                                                                              |
| Sevier County, Tenn.                      | 14.8                                                                                         | 5.2                                                                                          | 7.9                                                                                              |
| Tupelo, St. John the Baptist Parish, La.  | 12.4                                                                                         | 4.4                                                                                          | 7.9                                                                                              |
| Umbrella, Fraser, Sevier County, Tenn.    | 13.0                                                                                         | 4.4                                                                                          | 12.5                                                                                             |
| Walnut, black, Kentucky.                  | 11.3                                                                                         | 5.2                                                                                          | 7.1                                                                                              |
| Willow:                                   |                                                                                              |                                                                                              |                                                                                                  |
| Western black, Douglas County, Oreg.      | 13.8                                                                                         | 2.9                                                                                          | 9.0                                                                                              |
| Black, Sauk County, Wis.                  | 13.3                                                                                         | 2.2                                                                                          | 8.2                                                                                              |
| Witch hazel, Sevier County, Tenn.         | 18.8                                                                                         | (1)                                                                                          | (1)                                                                                              |
| <b>CONIFERS.</b>                          |                                                                                              |                                                                                              |                                                                                                  |
| Cedar:                                    |                                                                                              |                                                                                              |                                                                                                  |
| Incense—                                  |                                                                                              |                                                                                              |                                                                                                  |
| Lane County, Oreg.                        | (1)                                                                                          | (1)                                                                                          | (1)                                                                                              |
| Weed, Cal.                                | (1)                                                                                          | (1)                                                                                          | (1)                                                                                              |
| Port Orford, Douglas County, Oreg.        | (1)                                                                                          | (1)                                                                                          | (1)                                                                                              |
| Western red—                              |                                                                                              |                                                                                              |                                                                                                  |
| Missoula County, Mont.                    | 7.6                                                                                          | 2.5                                                                                          | 4.6                                                                                              |
| Snohomish County, Wash.                   | 8.6                                                                                          | 2.5                                                                                          | 5.6                                                                                              |
| White, Shawano County, Wis.               | 7.0                                                                                          | 2.1                                                                                          | 4.7                                                                                              |
| Cypress:                                  |                                                                                              |                                                                                              |                                                                                                  |
| Bald, St. John the Baptist Parish, La.    | 11.5                                                                                         | 3.8                                                                                          | 6.0                                                                                              |
| Yellow, Lane County, Oreg.                | (1)                                                                                          | (1)                                                                                          | (1)                                                                                              |
| Douglas fir:                              |                                                                                              |                                                                                              |                                                                                                  |
| Plumas County, Cal.                       | 11.7                                                                                         | 4.5                                                                                          | 6.9                                                                                              |
| Humboldt County, Cal.                     | (1)                                                                                          | (1)                                                                                          | (1)                                                                                              |
| Johnson County, Wyo.                      | 10.9                                                                                         | 3.7                                                                                          | 6.6                                                                                              |
| Lane County, Oreg.                        | 13.2                                                                                         | 5.7                                                                                          | 7.6                                                                                              |
| Chehalis County, Wash.                    | 12.5                                                                                         | 4.4                                                                                          | 7.4                                                                                              |
| Lewis County, Wash.                       | 12.3                                                                                         | 5.0                                                                                          | 8.3                                                                                              |
| Washington and Oregon.                    | (1)                                                                                          | (1)                                                                                          | (1)                                                                                              |
| Missoula County, Mont.                    | (1)                                                                                          | (1)                                                                                          | (1)                                                                                              |
| Fir:                                      |                                                                                              |                                                                                              |                                                                                                  |
| Amabilis—                                 |                                                                                              |                                                                                              |                                                                                                  |
| Dee, Oreg.                                | (1)                                                                                          | (1)                                                                                          | (1)                                                                                              |
| Snohomish County, Wash.                   | 14.1                                                                                         | 4.5                                                                                          | 10.0                                                                                             |

1 No figures available.

TABLE II.—Average shrinkage of various species of wood—Continued.

| Species and locality.                     | Shrinkage from a green to an oven-dry condition (per cent of dimensions when green).         |                                                                                              |                                                                                                  |
|-------------------------------------------|----------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
|                                           | Volume.<br> | Radial.<br> | Tangential.<br> |
| CONIFERS—continued.                       |                                                                                              |                                                                                              |                                                                                                  |
| Fir—Continued.                            |                                                                                              |                                                                                              |                                                                                                  |
| Alpine, Grand County, Colo.....           | 9.0                                                                                          | 2.5                                                                                          | 7.1                                                                                              |
| Balsam, Rusk County, Wis.....             | 10.8                                                                                         | 2.8                                                                                          | 6.6                                                                                              |
| Grand—                                    |                                                                                              |                                                                                              |                                                                                                  |
| Missoula County, Mont.....                | 10.9                                                                                         | 3.5                                                                                          | 6.8                                                                                              |
| Douglas County, Oreg.....                 | (1)                                                                                          | (1)                                                                                          | (1)                                                                                              |
| Noble, Multnomah County, Oreg.....        | 13.6                                                                                         | 4.9                                                                                          | 9.1                                                                                              |
| White, Madera County, Cal.....            | 10.2                                                                                         | 3.4                                                                                          | 7.0                                                                                              |
| Hemlock:                                  |                                                                                              |                                                                                              |                                                                                                  |
| Sevier County, Tenn.....                  | 11.6                                                                                         | 2.8                                                                                          | 7.8                                                                                              |
| Marathon County, Wis.....                 | 9.2                                                                                          | 2.3                                                                                          | 5.0                                                                                              |
| Mountain, Missoula County, Mont.....      | 10.8                                                                                         | 4.4                                                                                          | 7.1                                                                                              |
| Western—                                  |                                                                                              |                                                                                              |                                                                                                  |
| Chehalis County, Wash.....                | (1)                                                                                          | (1)                                                                                          | (1)                                                                                              |
| Grays Harbor and Buckley, Wash.....       | (1)                                                                                          | (1)                                                                                          | (1)                                                                                              |
| Larch, western:                           |                                                                                              |                                                                                              |                                                                                                  |
| Missoula County, Mont.....                | 13.2                                                                                         | 4.2                                                                                          | 8.1                                                                                              |
| Stevens County, Wash.....                 | (1)                                                                                          | (1)                                                                                          | (1)                                                                                              |
| Pine:                                     |                                                                                              |                                                                                              |                                                                                                  |
| Jack, Barron County, Wis.....             | 10.4                                                                                         | 3.4                                                                                          | 6.5                                                                                              |
| Jeffrey, Plumas County, Cal.....          | 9.9                                                                                          | 4.4                                                                                          | 6.7                                                                                              |
| Loblolly, Nassau County, Fla.....         | 12.6                                                                                         | 5.5                                                                                          | 7.5                                                                                              |
| Lodgepole—                                |                                                                                              |                                                                                              |                                                                                                  |
| Grand County, Colo.....                   | 11.3                                                                                         | 4.2                                                                                          | 7.1                                                                                              |
| Gallatin County, Mont.....                | 11.9                                                                                         | 4.6                                                                                          | 6.8                                                                                              |
| Granite County, Mont.....                 | 11.8                                                                                         | 5.0                                                                                          | 6.5                                                                                              |
| Jefferson County, Mont.....               | 12.0                                                                                         | 5.0                                                                                          | 6.9                                                                                              |
| Johnson County, Wyo.....                  | 10.1                                                                                         | 3.6                                                                                          | 5.9                                                                                              |
| Longleaf—                                 |                                                                                              |                                                                                              |                                                                                                  |
| Nassau County, Fla.....                   | 12.2                                                                                         | 5.1                                                                                          | 6.9                                                                                              |
| Bogalusa, La.....                         | (1)                                                                                          | (1)                                                                                          | (1)                                                                                              |
| Lake Charles, La.....                     | 12.8                                                                                         | 5.4                                                                                          | 7.8                                                                                              |
| Tangipahoa Parish, La.....                | 12.8                                                                                         | 6.0                                                                                          | 7.6                                                                                              |
| Hattiesburg, Miss.....                    | 11.0                                                                                         | 4.8                                                                                          | 7.5                                                                                              |
| Pitch, Sevier County, Tenn.....           | 11.7                                                                                         | 4.8                                                                                          | 7.4                                                                                              |
| Pond, Nassau County, Fla.....             | 11.2                                                                                         | 5.1                                                                                          | 7.1                                                                                              |
| Norway, Shawano County, Wis.....          | 11.5                                                                                         | 4.6                                                                                          | 7.2                                                                                              |
| Shortleaf—                                |                                                                                              |                                                                                              |                                                                                                  |
| Malvern, Ark.....                         | (1)                                                                                          | (1)                                                                                          | (1)                                                                                              |
| Bogalusa, La.....                         | (1)                                                                                          | (1)                                                                                          | (1)                                                                                              |
| Slash, Nassau County, Fla.....            | 12.7                                                                                         | 5.9                                                                                          | 7.5                                                                                              |
| Sugar, Madera County, Cal.....            | 8.4                                                                                          | 2.9                                                                                          | 5.6                                                                                              |
| Table-mountain, Sevier County, Tenn.....  | 10.9                                                                                         | 3.4                                                                                          | 6.8                                                                                              |
| Western white, Missoula County, Mont..... | 11.5                                                                                         | 4.1                                                                                          | 7.4                                                                                              |
| Western yellow—                           |                                                                                              |                                                                                              |                                                                                                  |
| Coconino County, Ariz.....                | 9.2                                                                                          | 4.1                                                                                          | 6.4                                                                                              |
| Madera County, Cal.....                   | 11.5                                                                                         | 4.9                                                                                          | 7.3                                                                                              |
| Douglas County, Colo.....                 | 9.9                                                                                          | 3.8                                                                                          | 5.8                                                                                              |
| Missoula County, Mont.....                | 9.3                                                                                          | 3.5                                                                                          | 5.9                                                                                              |
| White, Shawano County, Wis.....           | 7.8                                                                                          | 2.2                                                                                          | 5.9                                                                                              |
| Redwood:                                  |                                                                                              |                                                                                              |                                                                                                  |
| Humboldt County, Cal.....                 | (1)                                                                                          | (1)                                                                                          | (1)                                                                                              |
| Mendocino County, Cal.....                | (1)                                                                                          | (1)                                                                                          | (1)                                                                                              |
| Spruce:                                   |                                                                                              |                                                                                              |                                                                                                  |
| Engelmann—                                |                                                                                              |                                                                                              |                                                                                                  |
| San Miguel County, Colo.....              | 10.3                                                                                         | 3.0                                                                                          | 6.2                                                                                              |
| Grand County, Colo.....                   | 10.5                                                                                         | 3.7                                                                                          | 6.9                                                                                              |
| Red—                                      |                                                                                              |                                                                                              |                                                                                                  |
| Coos County, N. H.....                    | (1)                                                                                          | (1)                                                                                          | (1)                                                                                              |
| Sevier County, Tenn.....                  | 11.8                                                                                         | 3.8                                                                                          | 7.8                                                                                              |
| Sitka, Chehalis County, Wash.....         | 11.2                                                                                         | 4.5                                                                                          | 7.4                                                                                              |
| White—                                    |                                                                                              |                                                                                              |                                                                                                  |
| Coos County, N. H.....                    | (1)                                                                                          | (1)                                                                                          | (1)                                                                                              |
| Rusk County, Wis.....                     | 14.8                                                                                         | 3.7                                                                                          | 7.3                                                                                              |
| Tamarack, Shawano County, Wis.....        | 13.6                                                                                         | 3.7                                                                                          | 7.4                                                                                              |
| Yew, western, Snohomish County, Wash..... | 9.7                                                                                          | 4.0                                                                                          | 5.4                                                                                              |

<sup>1</sup> No figures available.



**HOW WOOD MAY BE INJURED IN SEASONING.****CHECKING.**

Checking is caused by unequal shrinkage. If the outside of a piece of wood dries considerably faster than the inside, the surface in time will contract until it can no longer extend around the comparatively wet interior, and so will be torn apart in checks. Checks often are classified as end checks and face checks. End checking or splitting during seasoning causes nearly as much loss as face checking.

**CASEHARDENING.**

Casehardening or surface hardening occurs when the surface of wood becomes set in a partially dry condition while the interior is still wet. This condition results from too rapid surface drying. If the interior of a casehardened piece of wood dries further, it tends to shrink, while the "set" condition of the surface tends to prevent it from doing so. As a result, stresses are set up in the piece. Plate I, figure 1, shows sections cut from casehardened boards, with a strip sawed from the center of each section. In *A*, the stresses cause the prongs to curve inward and bind on the saw. If the stresses are relieved by treatment with steam, as may be done sometimes, and the board dried a second time, the resawed prongs, as shown in *B*, will curve outward, owing to a reversal of the stresses. This is termed "reverse casehardening."<sup>1</sup>

Plate I, figure 2, shows the form taken by resawed pieces of kiln-dry boards steamed for different lengths of time. In No. 1 the prongs curve inward, owing to casehardening. No. 2 and No. 3 also show a casehardened condition as indicated by the strips curving inward. In Nos. 4, 5, and 6 the casehardening has been eliminated by longer steaming and the resawed strips are straight. No. 7, which has been steamed still longer, shows a condition of "reverse casehardening," in which the resawed strips curve outward.

Sections cut as shown in Plate I may be used also to determine the distribution of moisture in lumber, whether casehardened or not. If not casehardened, such sections will curve inward as they dry if the lumber is wetter on the inside than on the surface, and outward if the reverse is the case. If the lumber is uniformly dry, the prongs will remain practically straight.

**HONEYCOMBING.**

Honeycombing or internal checking occurs in casehardened pieces when the interior continues to dry and the surface remains fixed. In such cases splits appear in the interior. Plate II, figure 1, shows examples of honeycombing in casehardened pieces.

<sup>1</sup>For further discussion see "Problems in Kiln-Drying Lumber," by H. D. Tiemann, *Lumber World Review*, Sept. 25, 1915.

### WARPING.

Warping or twisting in lumber is due to unequal shrinkage. Some woods are much more subject to warping than others. The trouble can be prevented to some extent by careful piling, both during drying and afterward. Plate II, figure 2, shows badly warped pieces of lumber.

### COLLAPSE.

In some woods, notably western red cedar and redwood, when the very wet wood is dried at a high temperature, depressions appear on the surface of the boards, presumably due to the collapse of the plastic cell walls in certain places. If, however, the woods in question are heated above the boiling point while wet, the steam generated in the nonporous cells causes the wood to bulge on the surface. Plate III shows collapse and bulging, or "explosion," as it is termed by the discoverer of the phenomenon.<sup>1</sup>

### AIR-SEASONING.

Though the use of dry kilns is increasing steadily, the bulk of our wood is still seasoned in the open air. If kept in the air long enough, the moisture content of the wood finally comes into equilibrium with that of the surrounding atmosphere, and the wood is said to be air-dried. The rate of drying varies, of course, with time of year, species of wood, size and form of piece, and method of piling. Certain of these factors may be controlled or utilized in a way to hasten the drying process and lessen the likelihood of defects appearing in the material.

### CROSSTIES, POLES, AND SAWED TIMBERS.

The data in figures 2 to 12, inclusive, collected by the Forest Service<sup>2</sup> in various parts of the country, show the rate at which crossties, poles, and sawed timbers of several species lose moisture when freely exposed to the atmosphere. In some cases it was not possible to weigh the pieces for several days after they were cut. Freshly cut timber loses weight very rapidly in warm dry weather. Ties in some species lose 10 pounds in 24 hours. The rates of seasoning of the various species may be compared by the general trend of the curves. When the curves reach a horizontal position, the material may be said to be air-dry, unless this happens at a time of year very unfavorable for seasoning.

The ties were seasoned in piles of 50 each, and were exposed without cover. The ties on the top of each pile, however, were placed close together and served as a rough roof. The curves are platted

<sup>1</sup> H. D. Tiemann, in charge Section of Timber Physics, Forest Products Laboratory of Forest Service.

<sup>2</sup> See "The Air Seasoning of Timber," by W. H. Kempfer, Forest Service, in Bul. 161 of the American Railway Engineering Association.

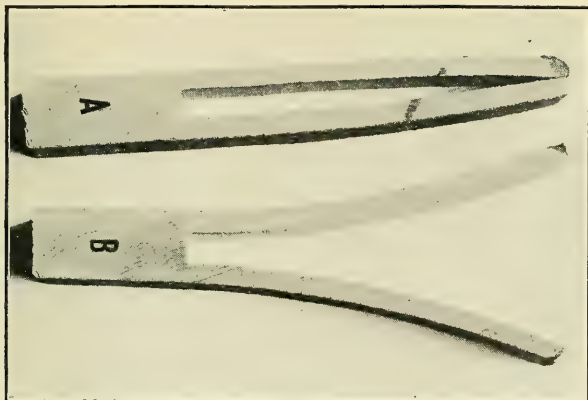


FIG. 1.—SECTIONS CUT FROM CASEHARDENED BOARDS.

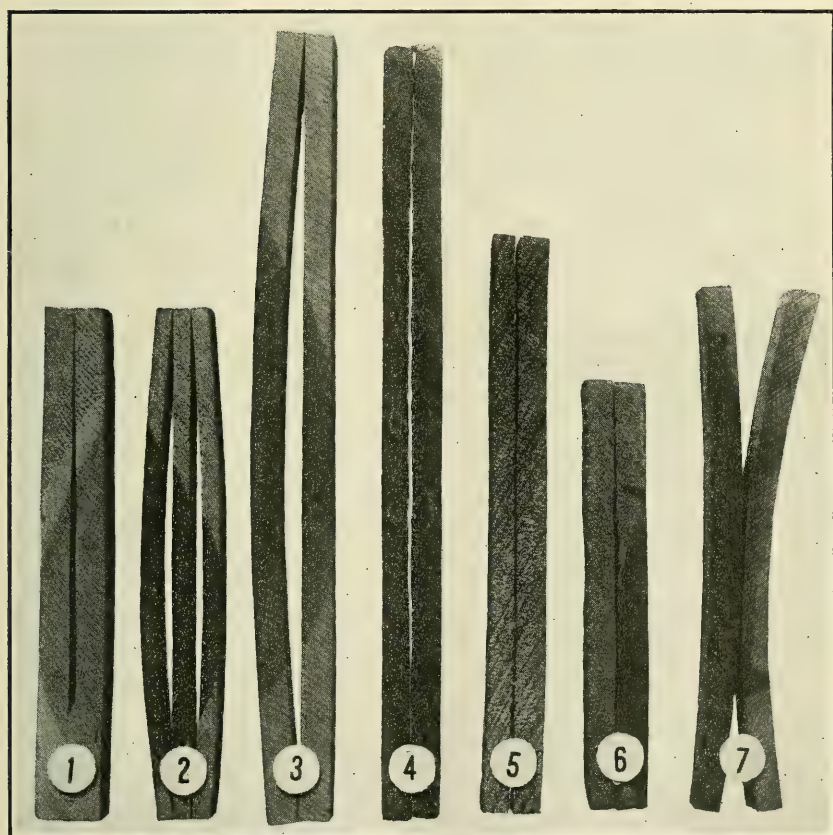


FIG. 2.—RESAWED SECTIONS CUT FROM CASEHARDENED RED GUM BOARDS STEAMED FOR DIFFERENT LENGTHS OF TIME AFTER BEING KILN DRIED.

(1) No final steaming; (2) and (3) 18 minutes final steaming; (4), (5), and (6) 36 minutes final steaming; (7) 3 hours final steaming.



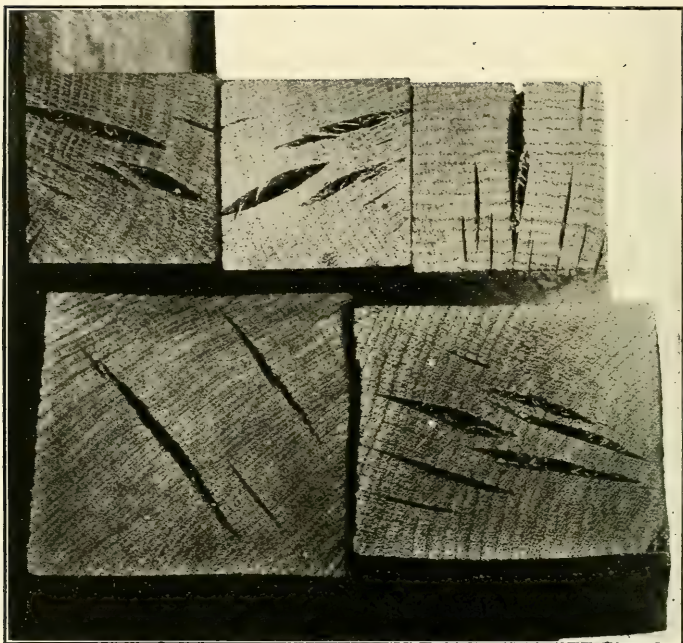


FIG. 1.—HONEYCOMBED OAK TIMBERS, THE RESULT OF CASEHARDENING.

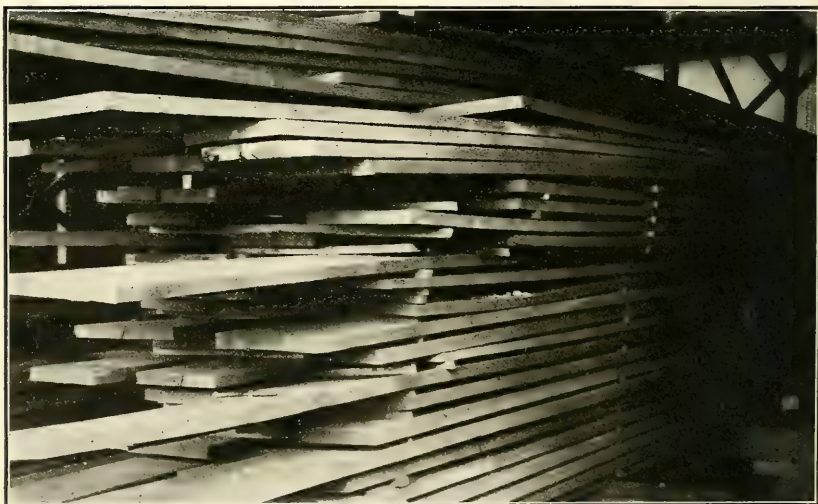


FIG. 2.—BADLY WARPED BOARDS.

The trouble here is due to a poor arrangement of stickers and to the piling together of boards of unequal length.

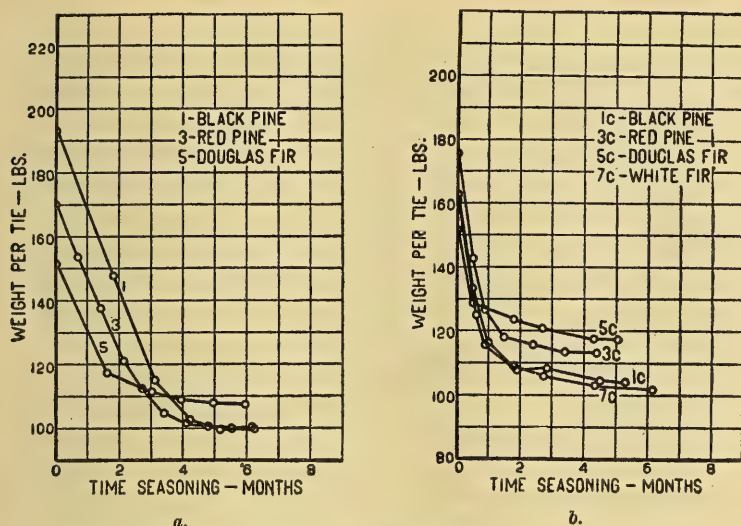


FIG. 2.—Southwestern ties. (a) Seasoning of ties at Pecos, N. Mex.; cut in January and February; (b) seasoning of ties at Pecos, N. Mex.; cut in August, September, and October. (Black and red pine are local names for western yellow pine; black pine refers to young trees and red pine to mature trees).

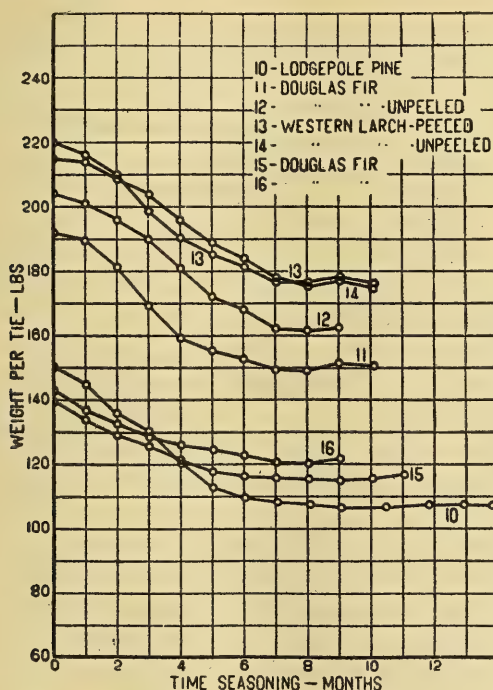


FIG. 3.—Northwestern ties. Seasoning of lodgepole pine ties at Bozeman, Mont., Douglas fir at Sandpoint, Idaho (curves 11 and 12), Pasco, Wash. (curve 15), and Tacoma, Wash. (curve 16); and western larch at Sandpoint, Idaho, cut in January and February; Tacoma ties in December and January.

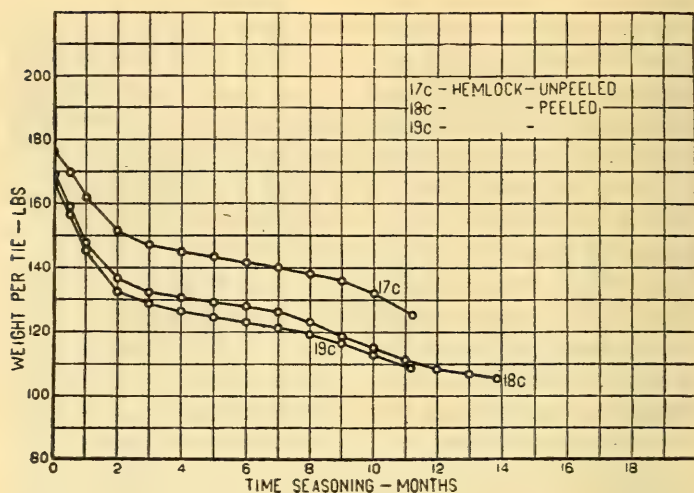


FIG. 4.—Seasoning of hemlock ties at Escanaba, Mich.; cut in August and September.

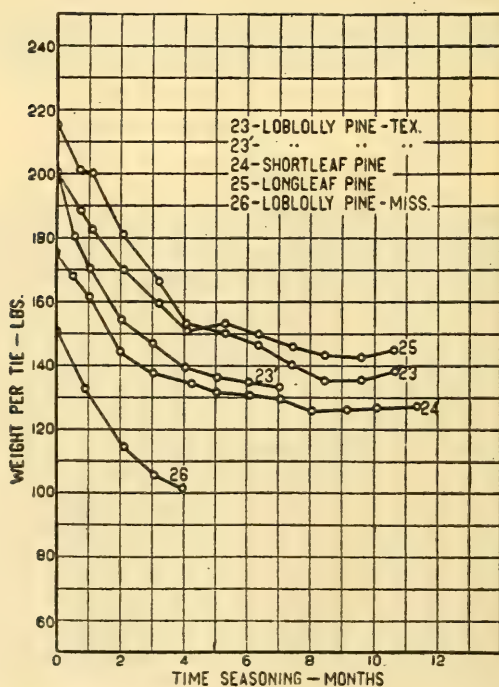


FIG. 5.—Seasoning of ties at Silsbee, Tex., and Ackerman, Miss.; cut in January and February.



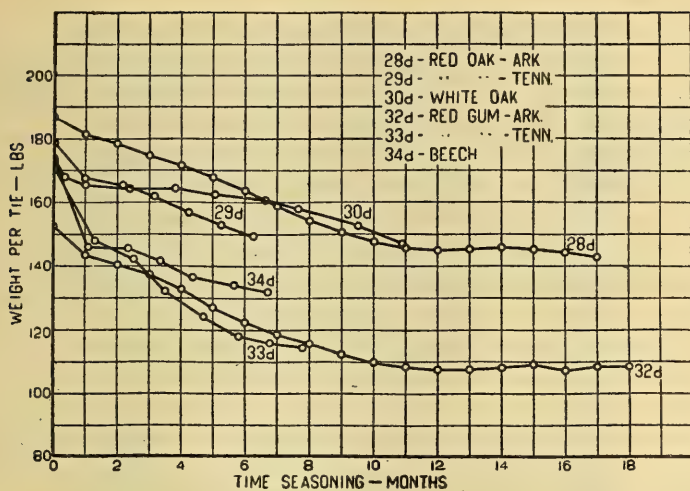


Fig. 6.—Seasoning of hardwood ties in Southern States; cut in October, November, and December.

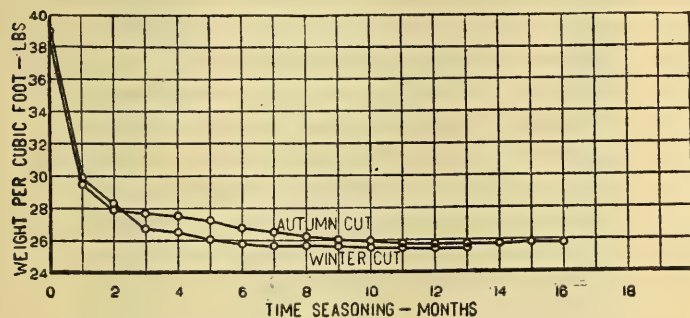


Fig. 7.—Seasoning of southern white cedar poles at Wilmington, N. C.

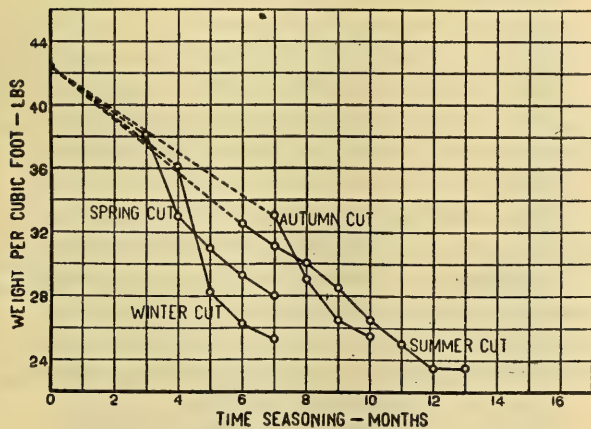


Fig. 8.—Seasoning of western red cedar poles at Wilmington, Cal.

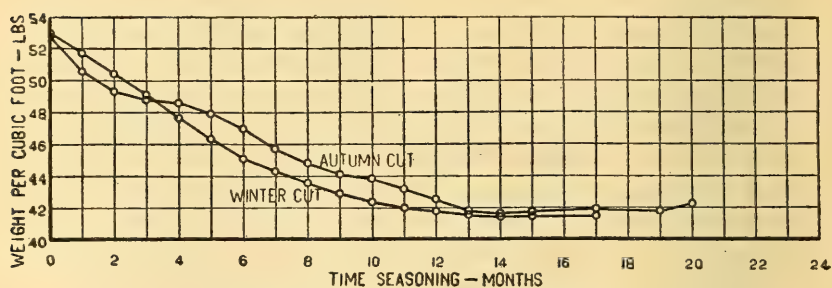


FIG. 9.—Seasoning of chestnut poles at Thorndale, Pa.

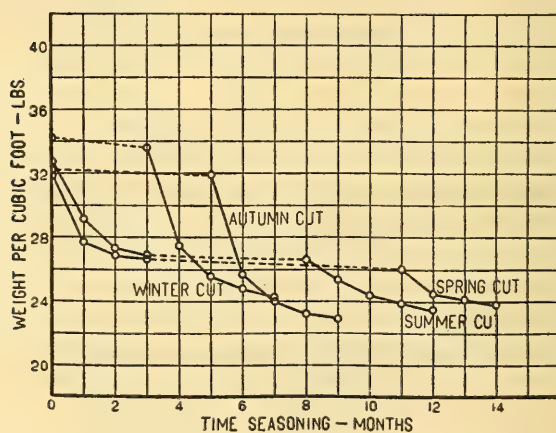


FIG. 10.—Seasoning of northern white cedar poles at Escanaba, Mich.

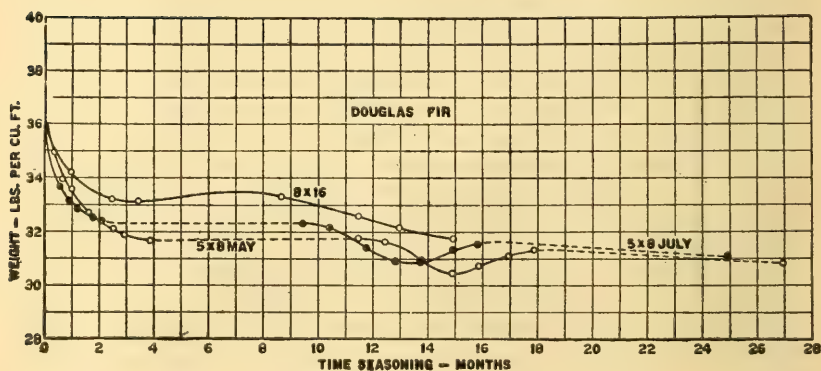
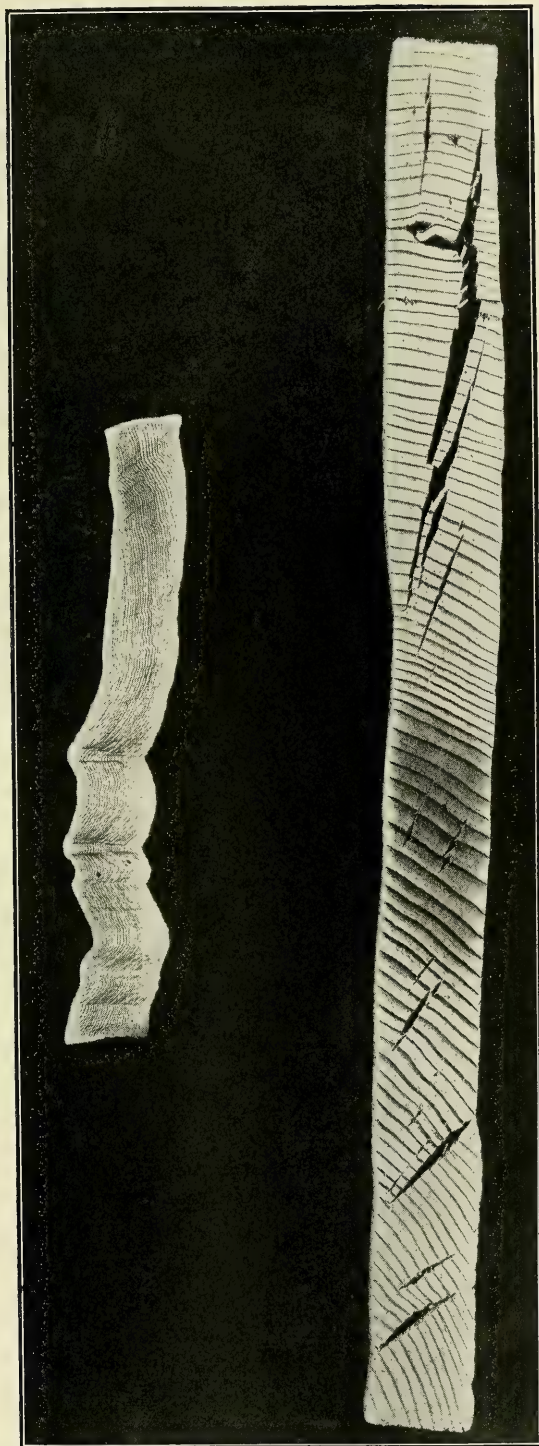


FIG. 11.—Seasoning of Douglas fir timbers at Eugene, Oreg.



COLLAPSE AND BULGE IN VERY WET LUMBER DRIED AT A HIGH TEMPERATURE.



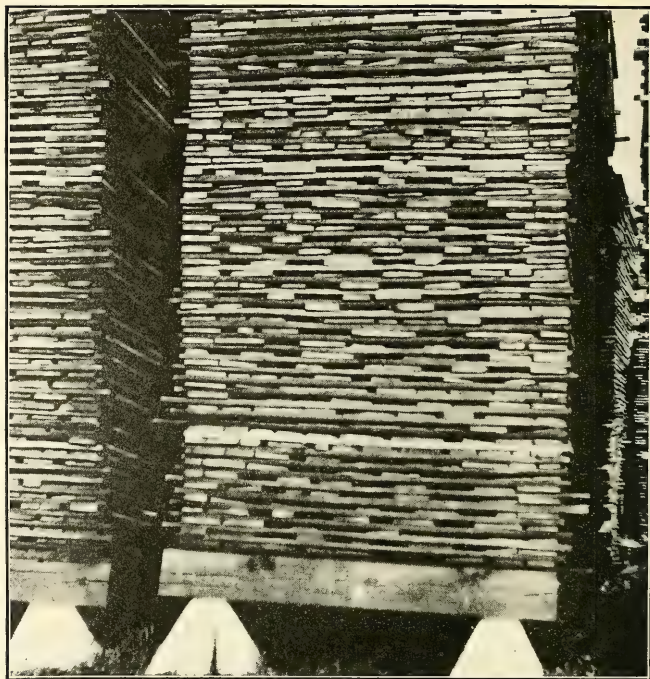


FIG. 1.—CEMENT AS FOUNDATION MATERIAL.

These blocks extend 2 feet above and 2 feet into the ground.

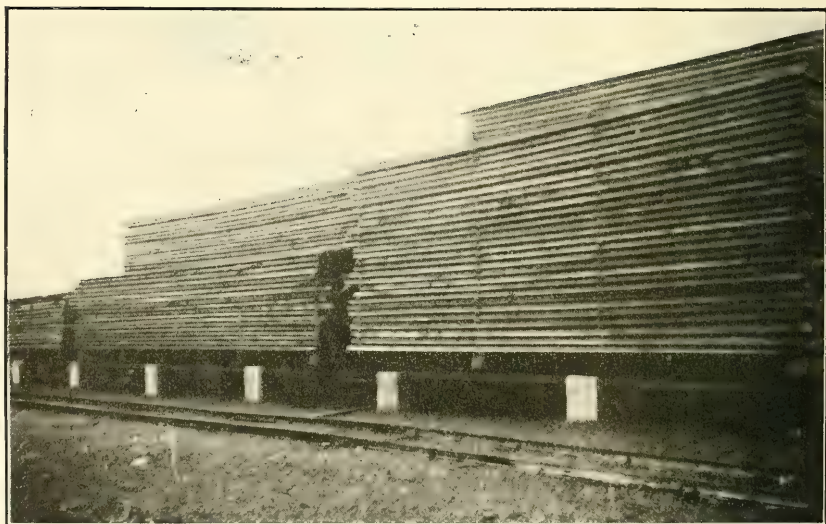


FIG. 2.—ANOTHER TYPE OF PERMANENT FOUNDATION.

Steel rails are embedded in cement piers. The lumber is fully 2½ feet above the ground, insuring excellent ventilation.

from the average weight of the ties. The weight per unit volume could not be used, as in many cases the volumes of the ties were not

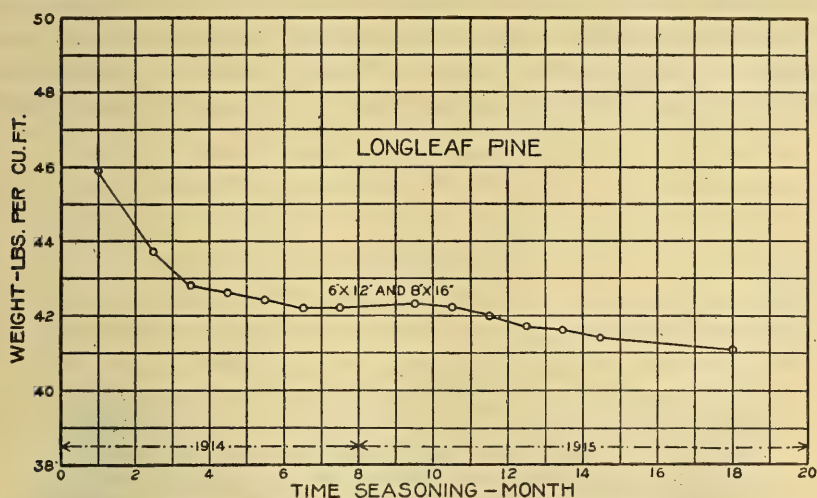


FIG. 12.—Seasoning of longleaf pine timbers at Madison, Wis.

obtained. The poles were seasoned on skids in the open. The sawed timbers were seasoned in open piles under shelter.

#### LUMBER.

Sawed lumber generally is dried by being piled in stacks with air spaces between the boards. In forming the stacks the boards usually are laid flat, with strips called stickers between courses or layers.

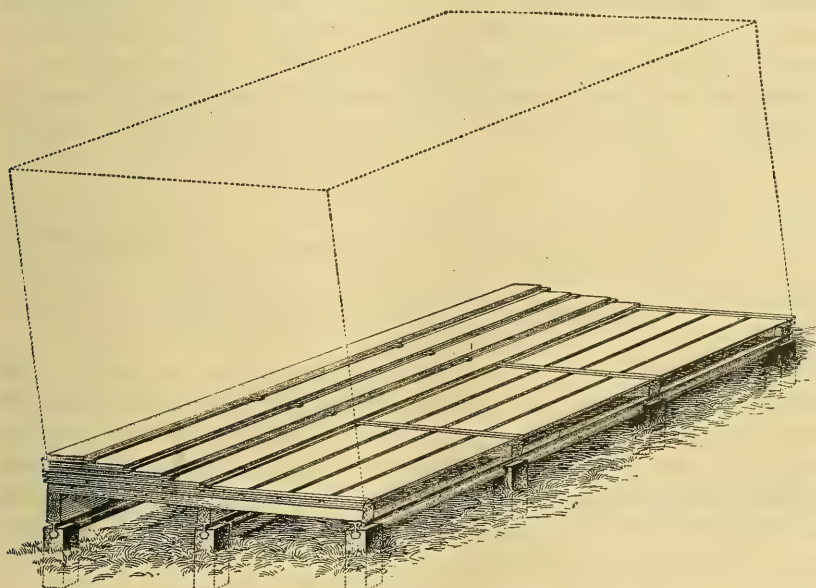


FIG. 13.—Lumber piled sidewise on cement and metal foundations.

A space also is left between each board in a layer and the adjacent board to provide for the circulation of air throughout the stack. Flat or horizontal piling may be of two kinds: (*a*) With the ends of the boards toward the alley—endwise piling, and (*b*) with the sides toward the alley—sidewise piling. Figures 13 and 14 illustrate the two methods. The stacks are arranged to slope from front to rear,

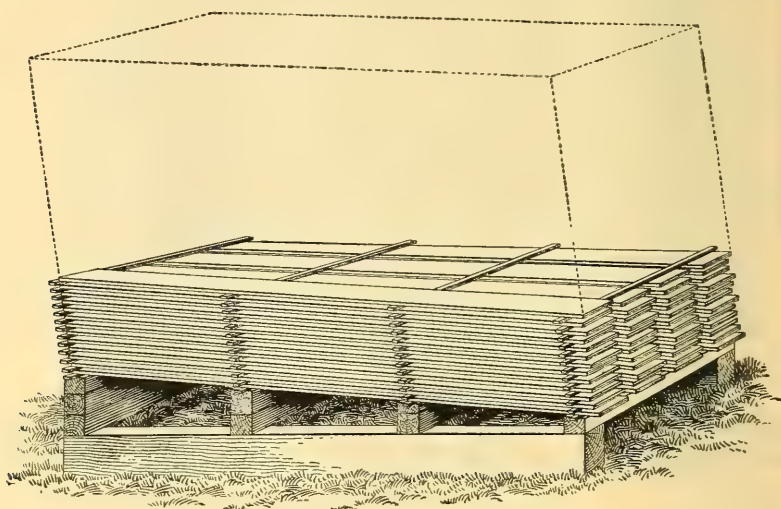


FIG. 14.—Lumber piled lengthwise on wooden foundation.

and to lean forward so that water dripping from the top falls to the ground without trickling down over the courses below. With either method of piling the stacks should be so located in the yard that the prevailing winds blow through them rather than against the ends.

Most lumber manufacturers and dealers use the endwise method of piling. A number, however, have adopted the sidewise method,



FIG. 15.—Method of providing drainage under lumber piles.

which has certain advantages in the matter of air circulation. In endwise piling the stickers obstruct the passage of air from back to front of a course, while in sidewise piling the passages from front to rear are clear. Water which forces its way into the pile is more efficiently drained in sidewise piling, and the likelihood of sticker rot and discoloration due to the accumulation of moisture, dust, and dirt against the stickers is lessened.



The bottom boards in a stack rest on skids, which in turn rest on foundations, preferably of stone, cement, or metal. Pieces containing rot should never be used for foundation timbers or skids, or allowed to remain in the pile. The vicinity of the pile should be kept clear of weeds.

The use of cement and metal foundations is especially feasible in retail lumber yards and in those maintained by wood-using factories. In retail yards, where economy in space often is the essential thing, the piles are high and a particular space usually is allotted to each class or species of lumber. In factory yards lumber often is held for a number of years before being used. In such cases the frequent renewal of wooden foundations under lumber piles entails considerable expenditure of time and money, to say nothing of the danger of infecting lumber by bringing it in contact with partly rotted foundation timbers. For these reasons foundations of a more permanent character are constantly growing in favor in retail and factory yards. Plate IV shows foundations of this kind.

Sawmill yards, on the other hand, often contain several million feet of material and cover several acres. Lumber coming from the saw generally is piled wherever most convenient, provided it is placed at the distance from the mill required by insurance companies. Economy in storage space generally is not essential, and piles of the same species and kind of lumber are likely to be found in a number of different sections of the yard. In addition, the stock is constantly being turned over, thus giving an opportunity to renew the foundation timbers at comparatively small expense. A number of large lumber companies, however, have adopted cement as a foundation material.

Lumber-storage yards need to be reasonably well drained, or at least the contour of the ground should be such that water will not stand under the stacks after a storm. Otherwise decay is apt to get a start and spread throughout the pile. Where the ground offers but poor natural drainage facilities, some artificial system of drainage usually is employed. Figure 15 shows the system used in the yards of two large lumber companies in the southern hardwood region. This arrangement not only prevents the collection of rain water under the lumber piles, but also gives the required slope to the stack, which on level ground has to be secured by building up the foundations.<sup>1</sup>

A top dressing of cinders has been found satisfactory in some storage yards.

The following set of rules for piling lumber covers the more important points to be observed in the construction of foundations, shape of stack, arrangement of stickers, etc.:

---

<sup>1</sup> Humphrey, C. J. Timber Storage Conditions in the Eastern and Southern States, with reference to Decay Problems. U. S. Dept. Agr. Bul. 510. 1917.

## RULES FOR PILING LUMBER.

### 1. FOUNDATIONS (ENDWISE OR SIDEWISE PILING).

- (a) The foundations should be strong, solid, and durable.
- (b) The top of each foundation should be level, and from front to back the top surface of the parallel skids should be in alignment, so that the lumber to be piled will bear equally upon each one.
- (c) The front foundation should be raised above the second, and the second above the third, to allow a slant in the stack of 1 inch to every foot.
- (d) The foundations should be spaced not over 4 feet apart, except for heavy planks and timbers.
- (e) The front foundation should be of sufficient height to provide space for free circulation of air under all parts of the pile.

### 2. LUMBER (ENDWISE PILING).

- (a) Skids, preferably 2 by 4 inches, should be laid on top of the foundations.
- (b) Boards of equal length should be piled together.
- (c) The ends of the boards should rest upon the front and rear skids.
- (d) A space of approximately three-fourths inch should be left between boards in the same layer.
- (e) Lumber piled in the open should have the front ends of boards in each layer slightly protruding beyond the end of the layer beneath, to give a forward pitch to the stack.

### 3. LUMBER (SIDEWISE PILING).

- (a) Skids, preferably 4 by 6 inches, should be placed across the foundations at about 4-foot intervals. The number of skids depends upon the thickness of the lumber.
- (b) Boards of equal length should be piled together.
- (c) The boards should be placed on the skids, with about three-fourths inch between boards in the same layer.
- (d) Lumber piled in the open should have the front board in each layer project slightly beyond the board in the layer beneath, to provide a forward pitch to the stack.

### 4. STICKERS (ENDWISE OR SIDEWISE PILING).

- (a) Stickers should be of uniform thickness, preferably seven-eighths inch for 1-inch lumber and  $1\frac{1}{2}$  inches for 2-inch lumber. Their length should be a few inches in excess of the width of the pile.
- (b) Stickers should be placed upon the layer of boards immediately over the skids and kept in alignment parallel to the front of the piles.
- (c) The front and rear stickers should be flush with, or protrude beyond, the ends of the boards.

### 5. ROOF PROTECTION (ENDWISE OR SIDEWISE PILING).

Cover boards, as a roof protection, should be laid on the top of the pile, extending a few inches beyond the front and rear ends of the stack.

### 6. SPACING STACKS (ENDWISE OR SIDEWISE PILING).

Space between the piles should not be less than 2 feet; 4 or 5 feet is preferred if yardage conditions permit.



FIG. 1.—SUN SHIELDS USED TO REDUCE CHECKING IN THICK RED OAK TIMBER.

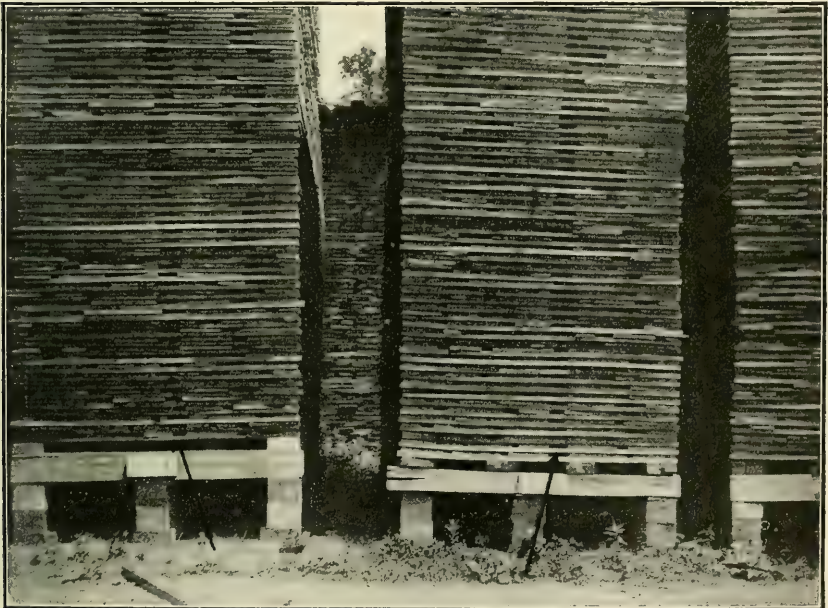


FIG. 2.—LUMBER PILED SO AS TO FORM "CHIMNEY" OR FLUE NEAR CENTER OF STACK FROM BOTTOM TO TOP.



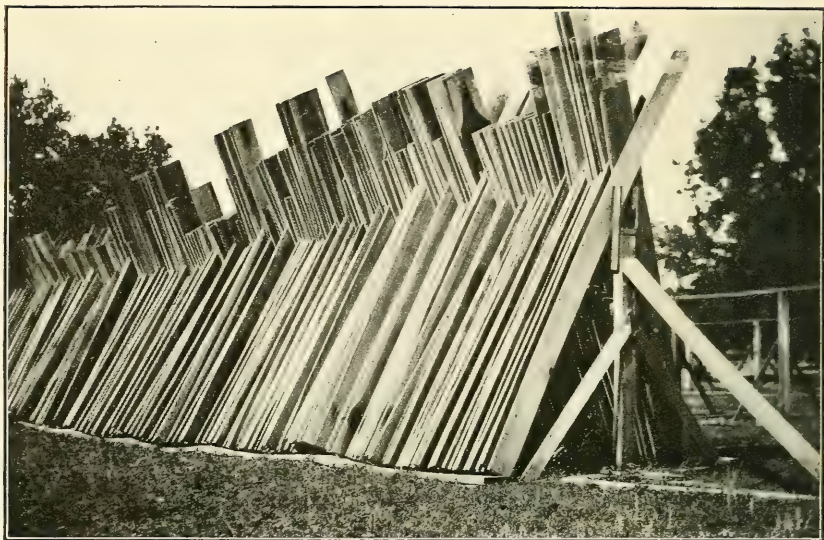


FIG. 1.—POLE DRYING YELLOW POPLAR LUMBER.

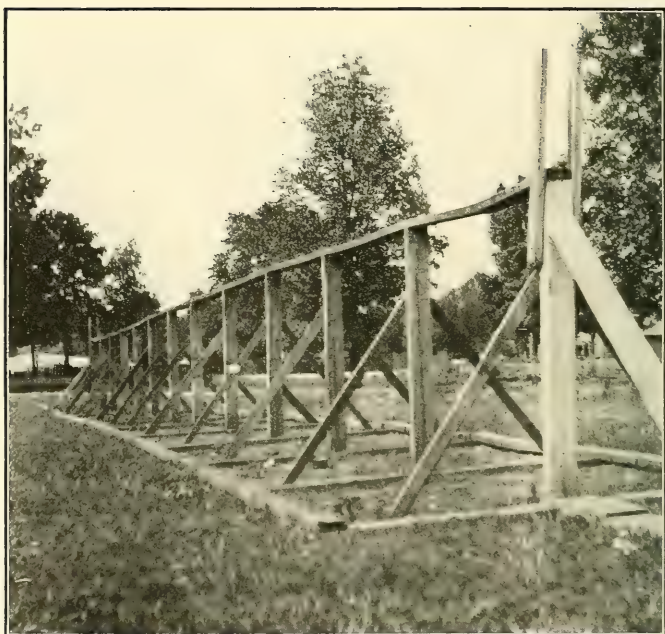
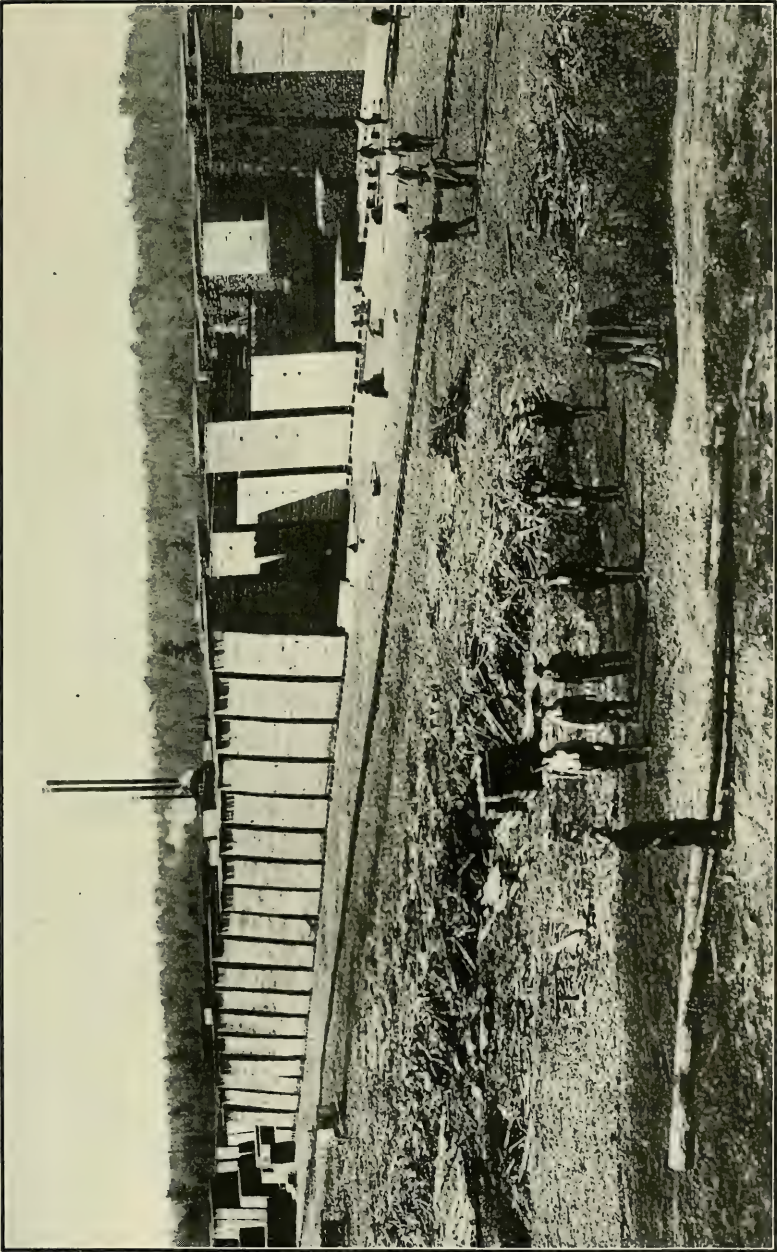
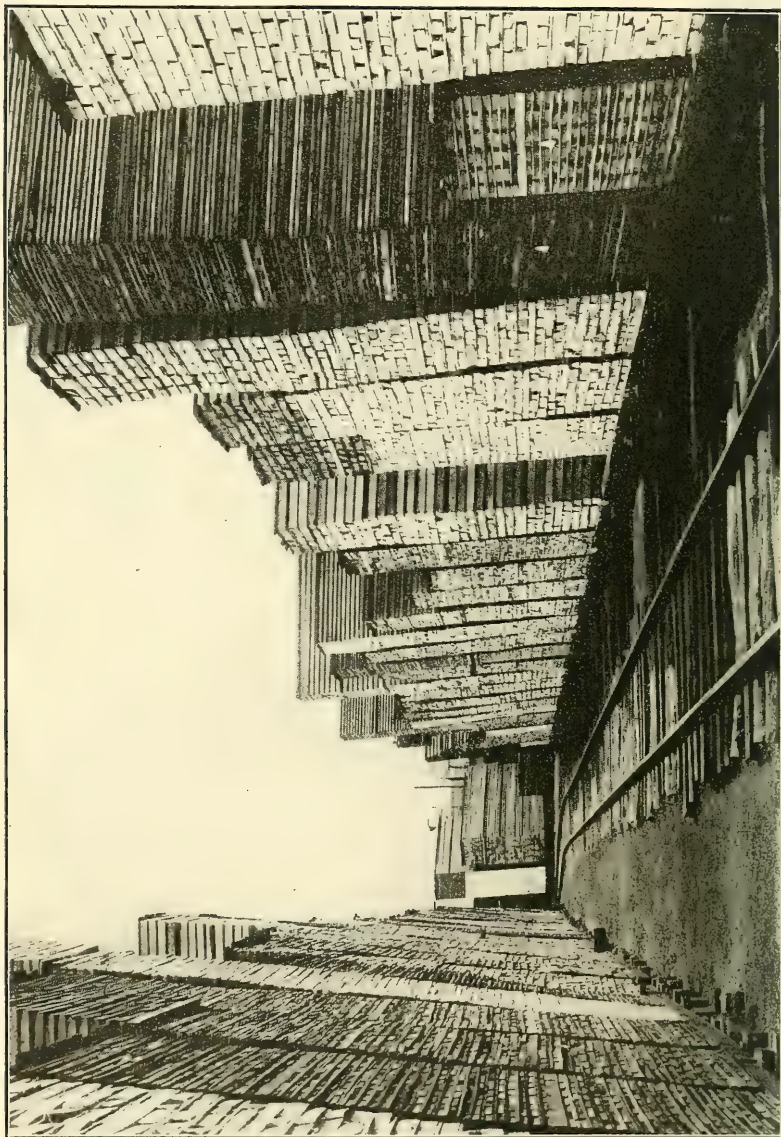


FIG. 2.—POLE FRAMEWORK USED TO DRY YELLOW POPLAR, BASSWOOD, AND COTTONWOOD BEFORE PLACING IT IN A STUCK PILE.



LUMBER YARD OF A SAWMILL IN THE LAKE STATES.  
Note fine appearance of lumber piles.





A WELL-KEPT LUMBER YARD MAINTAINED BY A LARGE EASTERN WOOD-USING FACTORY.

Note forward pitch of stacks, treated ends, and general clean sanitary ground conditions.



## 7. DIMENSIONS OF STACK (ENDWISE OR SIDEWISE PILING).

The customary width of stacks is from 8 to 16 feet. The height is governed by the size and character of the lumber and by the methods of moving it.

## 8. TREATED ENDS (ENDWISE OR SIDEWISE PILING).

The ends of lumber  $2\frac{1}{2}$  inches thick or over, unless of the lower grades, should receive a brush treatment of paint or some liquid filler.

The rules just given are based on information obtained through field investigations and from lumber manufacturers and wholesale and retail dealers, and accord with the best lumber-piling practice in general commercial use. Certain species of wood, however, require particular care in air-drying, and in this case slight variations from the rules are necessary in order to secure the best results. Some lumbermen in the South, for example, find that thick red oak checks badly on the ends, and in air-drying such stock have adopted the scheme of protecting it with sun shields, as shown in Plate V, figure 1, which they claim reduces end-checking to a minimum.

Mills cutting red gum formerly experienced difficulty in drying the lumber, on account of its tendency to warp. This objection, however, has been largely overcome by the exercise of care in seasoning. In erecting a pile of gum lumber, stickers are placed every 2 feet apart, some lumbermen claiming that 18 inches in none too close to obtain the best results. Another scheme in more or less general use among gum-lumber manufacturers is to construct the pile so as to have a flue or "chimney" in its center, thus providing ample air circulation vertically through the stack, as shown in Plate V, figure 2.

Green cottonwood, basswood, and yellow poplar lumber is likely to stain badly when piled. Accordingly, a number of lumbermen either end-dry the material or pole-dry it for a week or two and then place it in a "stuck" pile. In end-drying, the boards are stood up on end, edge to edge, under a specially built shed, with stickers arranged horizontally one above the other at specified distances. Such a pile presents exactly the appearance of a regular lengthwise pile of lumber set up on end.

Plate VI, figure 1, shows a quantity of yellow poplar lumber being pole-dried, while Plate VI, figure 2, shows the frame used for the purpose.

Hickory and ash lumber frequently check badly when air-dried. Lumbermen in the southern hardwood region have found that these checks will close up entirely if the lumber is first stuck-piled for 6 to 8 months and then bulk-piled and protected by good covering, preferably sheds.

Plates VII and VIII show lumber piles in yards where careful attention has been given to the matter of piling and yard arrangement.

### KILN-DRYING.

Lumber is kiln-dried when there is need for seasoning it quickly, or when the manufacturer does not wish to carry large stocks in his yard. A kiln is used also to further dry partially air-seasoned or even fully air-seasoned material, for special uses.

The main problem in kiln-drying lumber is to prevent the moisture from evaporating from the surface of the pieces faster than it is brought to the surface from the interior. When this happens the surface becomes considerably drier than the interior and begins to shrink. If the difference in moisture content is sufficient, the surface portion opens up in checks.

The evaporation from the surface of wood in a kiln can be controlled to a large degree by regulating the humidity, temperature, and amount of air passing over the wood; and a correctly designed kiln, especially one for drying the more difficult woods, should be constructed and equipped in a way to insure this regulation.

A dry kiln may consist simply of a box in which lumber can be heated, or of a good-sized building or group of buildings (battery) containing steam pipes, condensers, sprays, and various air passages capable of adjustment to regulate the amount of ventilation. The elaborateness of the kiln depends, of course, mainly upon the value of the lumber that is to be dried. For lumber worth \$100 per 1,000 board feet, it obviously will pay to use more careful drying methods than in handling material valued at \$20 or \$25 per 1,000 board feet.

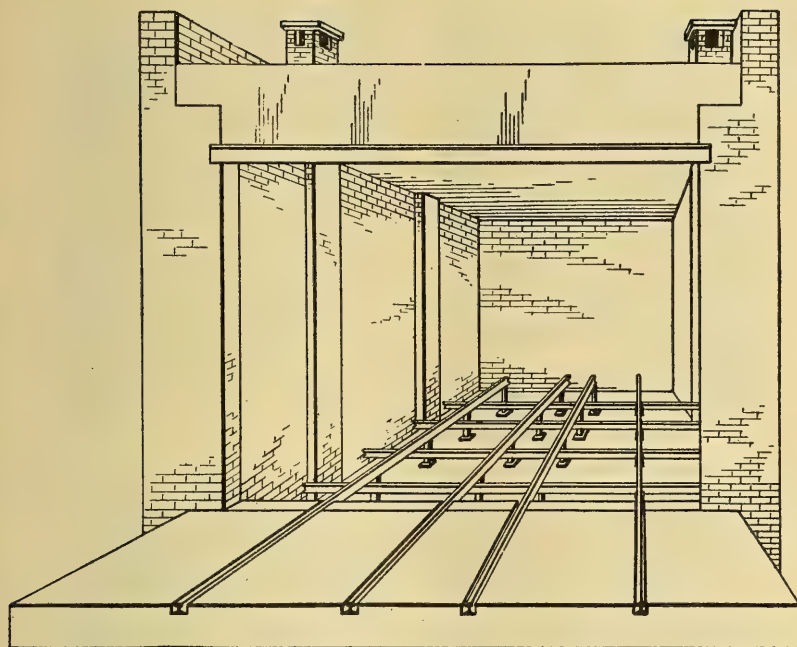
#### TYPES OF KILNS.

Kilns for drying lumber may be divided into two general classes (fig. 16): (a) compartment kilns, and (b) progressive kilns. In compartment kilns the conditions are changed during the drying process, and all lumber in the kiln is dried at one time. The conditions at any time during drying are uniform throughout the whole kiln. In a progressive kiln conditions at one end differ from those at the other, and the lumber is dried progressively by being passed through the kiln. Compartment kilns are used when it is desired to dry lumber of various sizes and species, while progressive kilns are used where uniform stock is handled.

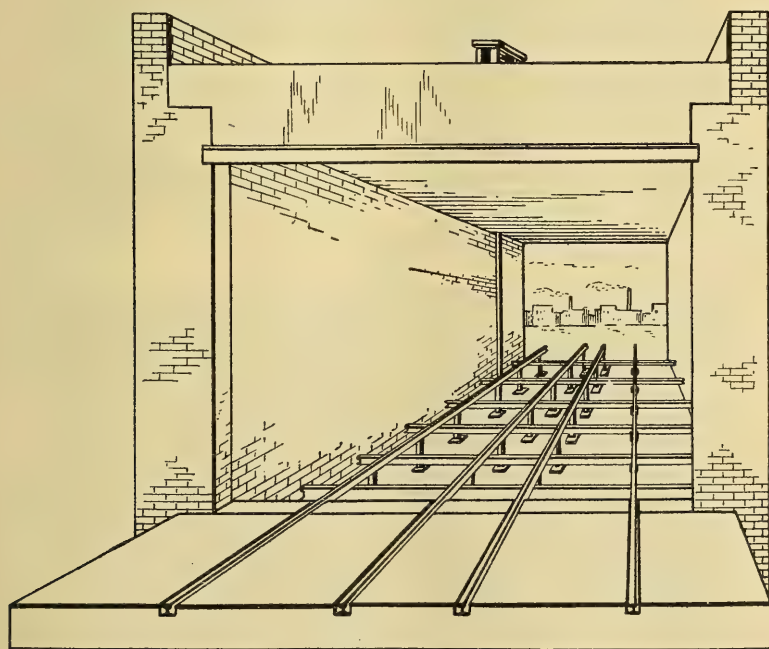
The methods of operation generally used in lumber kilns are: (a) natural ventilation, (b) condensing, and (c) superheated steam.

In kilns operating by natural ventilation, the humidity or dampness is controlled by the use of escaping steam and evaporated moisture. Circulation in progressive kilns is largely longitudinal and in compartment kilns transverse. Moist air is allowed to escape from the kiln.

In condensing kilns the humidity is controlled by recirculating the air, which has taken up water from the lumber, across water pipes



COMPARTMENT KILN



PROGRESSIVE KILN

FIG. 16.—Types of kilns.



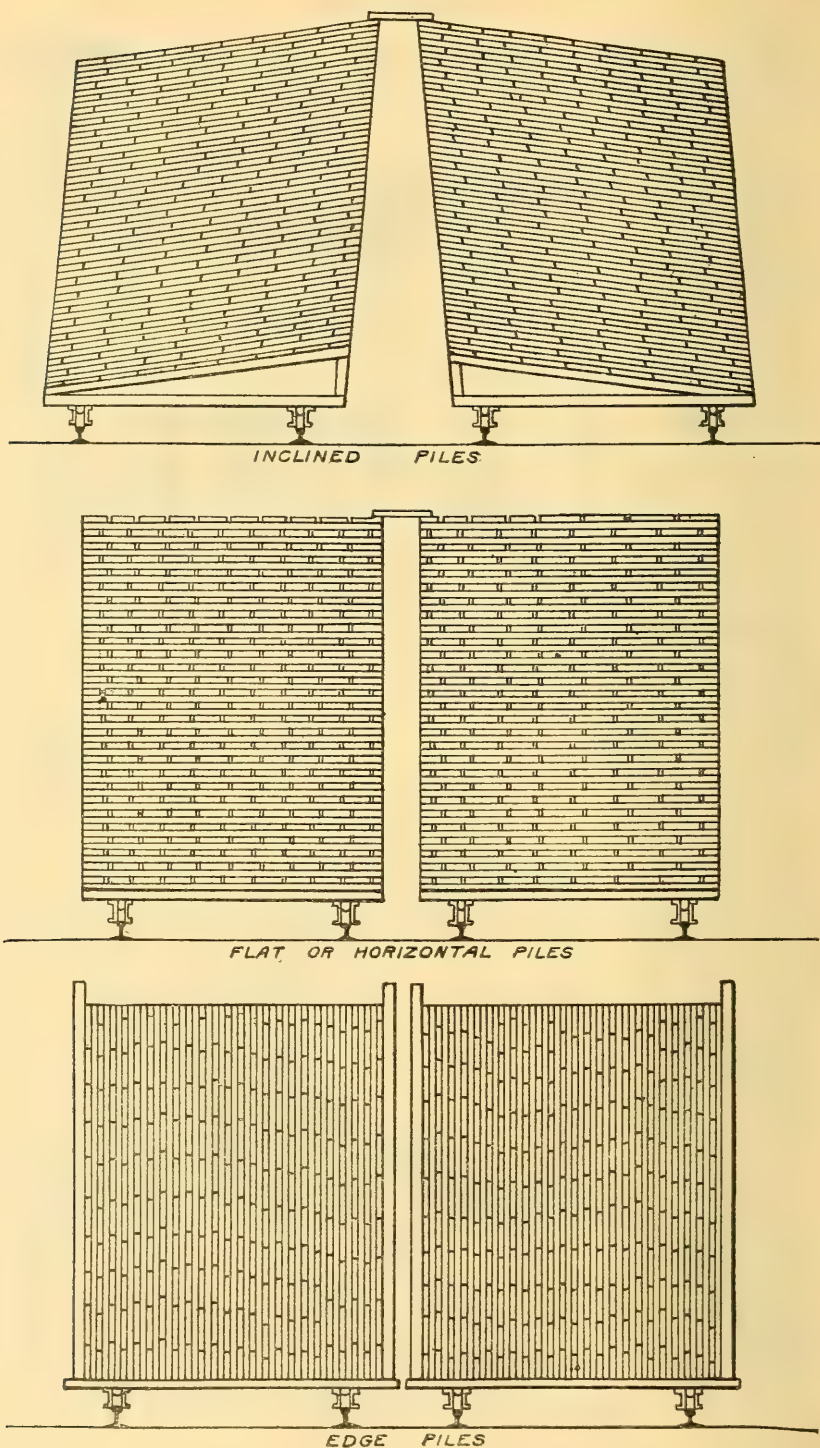


FIG. 17.—Methods of piling lumber for kiln drying.

or through water sprays. The temperature of the pipes or sprays governs the amount of water that condenses from the air, and consequently regulates the humidity of the air when reheated before being passed over the lumber again. The circulation of air may be either natural or forced. Condensing kilns are generally of the compartment type.

Kilns operating with superheated steam are used only where the species to be dried are not injured by high temperatures, and where fast drying is essential.

Lumber may be piled on the trucks which carry it into the kiln in any one of three ways (fig. 17): (a) flat or horizontal, (b) edge or vertical, and (c) inclined. Flat piling is best for longitudinal circulation. It is not so well adapted for transverse circulation, and is not economical for downward circulation. Vertical piling increases the truck capacity, as there are no vertical spaces between the boards. Probably it is the best method for downward or any fast circulation. Provision has to be made, however, for keeping the boards in place in the stack. Inclined piling allows for a definite movement of air either downward or upward (forced draft). It is an improvement, as regards circulation, over horizontal or flat piling.

Some kiln operators using the flat or horizontal method of piling report excellent results from the construction of a V-shaped opening in the center of the truck pile. Such openings are from  $2\frac{1}{2}$  to 3 feet wide at their base, and from  $3\frac{1}{2}$  to 4 feet high. Where this practice is followed it is customary also to place the boards in the layers closer together as the top of the stack is reached, to force greater lateral circulation.

In loading lumber on kiln trucks by any one of the three methods mentioned, the stickers should be of a uniform thickness and arranged in the piles in alignment.

It is advisable also not to attempt to dry various thicknesses of lumber together. Thick lumber takes longer to dry than thin lumber, and when different thicknesses are mixed the operation has to be governed by the thick stock, to the possible detriment, or at least the unnecessarily long drying, of the thin stock.

#### PRELIMINARY TREATMENTS.

Lumber to be kiln-dried is sometimes steamed in a separate compartment before being placed in the kiln proper, especially where the kiln is not designed for moist-air treatment. In transferring lumber from a compartment for preliminary treatment to the kiln proper, every care must be used to avoid a sudden change in humidity. The object of the steaming is to heat the lumber and thus make easier the transmission of moisture from the interior to the surface, and also to moisten the surface in case it has become casehardened or "set"

during partial air drying. Other effects, also, are produced, which to a greater or less extent change the properties of the wood. The "sap" in the wood is changed by "cooking," as indicated by a darkening of the wood, the degree of coloring depending upon the temperature and duration of the process. Other changes of a chemical nature apparently also take place in the wood during steaming.

The pressure and duration of steaming desirable in kiln-drying have not yet been thoroughly worked out. Durations of from 5 minutes to 24 hours or longer, and pressures ranging from atmospheric to 50 pounds gauge, have been used in practice. The higher the pressure the greater is the effect produced, and the longer the time the more thoroughly the treatment penetrates the wood. Experiments have shown that a pressure slightly above atmospheric for 24 hours will slightly darken 2-inch maple clear through, and a pressure of 40 pounds will turn oak and probably other hardwoods almost black. Even where the strength of the wood is not the primary consideration, it probably is not safe to exceed 15 pounds gauge pressure (250° F.), except for special purposes.

#### THE PROCESS OF DRYING.

After the wood has been heated thoroughly in a humid atmosphere, either in the kiln proper or in a separate compartment, it is ready to have the moisture removed by evaporation from the surface. In kiln-drying uniform circulation apparently is the most important thing to be secured. The fact that air when it enters the drying chamber will be cooled, and therefore will tend to fall, should govern the method of piling and the direction of circulation.<sup>1</sup> This means that the air should be allowed and assisted to pass downward through the pile, either by entering at the top of the pile or by an adaptation of this principle to other methods of piling. The rate of evaporation may be controlled best by regulating the amount of moisture in the air (relative humidity) circulating about the lumber in the kiln; it should not be controlled by reducing the air circulation, since a large circulation is needed at all times to supply the necessary heat. Air at 100 per cent relative humidity contains all the water it can carry and has no effect in drying wood. If, however, the humidity is reduced to 90 per cent and the air then passed through a pile of wet lumber, the air can take up a certain amount of moisture. If drying does not progress rapidly enough with the circulating air at 90 per cent humidity, it may be reduced still further. This may be accomplished by ventilation, by condensers, by water or steam sprays, or in a number of other ways. Any well-made kiln which will allow the control of the humidity, temperature, and cir-

<sup>1</sup> See "The Circulation in Dry Kilns," by H. D. Tiemann, *Lumber World Review*, May 10 and June 10, 1916.



culatation of the air passing over the lumber should give satisfactory results. If checking begins during the drying process, the humidity should be increased until it stops. Steam jets in a kiln are often useful for this purpose. In changing the humidity the circulation should not be reduced. A large body of moving air is necessary in order to keep a uniform temperature clear through to the center of each piece of wood in the pile and at the same time supply the heat required for evaporation. If sufficient circulation is not secured, the supply of heat for both purposes will be lacking and the material will not dry uniformly. Figure 18 shows the conditions in a kiln during a run with reference to temperature, humidity, and moisture in the wood. It will be noted that the humidity is kept high at first and lowered gradually. The temperature is held at a certain level for some time and then raised. The moisture is lowered gradually to a final condition of less than 5 per cent.

The maximum rate of drying at a given temperature is reached when moisture is evaporated from the surface of the wood just as fast as it is transmitted from the interior. This rate is fixed by the rate of transmission of moisture within the wood and varies with different woods.

The temperature of drying apparently influences the rate of transmission of moisture within

the wood. The higher the temperature of the wood the more rapid is the rate of transmission of the moisture, and hence the rate at which the moisture may be evaporated safely. This, of course, applies only to temperatures below those which might result in injury to the wood.

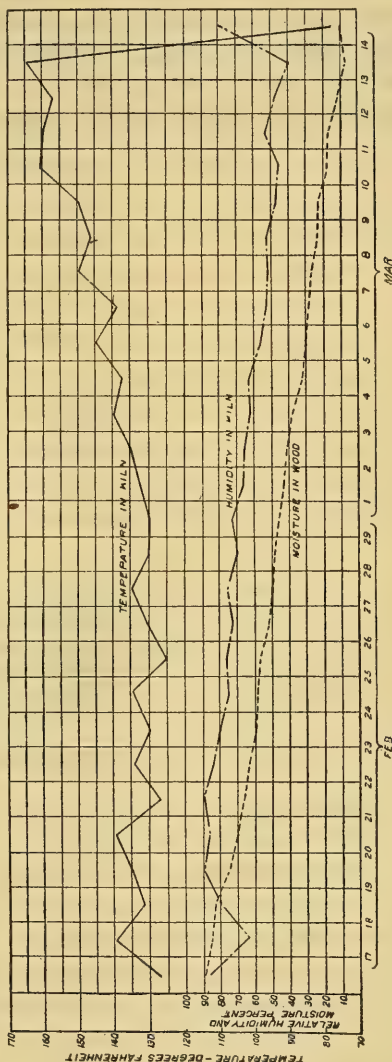


FIG. 18.—Typical conditions in a kiln during a run.

Drying tends to render wood more or less brittle. Although the strength of wood increases with its degree of dryness, yet wood which has been dried and resoaked is less resilient than when green. Therefore, where strength is the prime consideration, it is preferable not to dry the wood beyond the degree at which it is to be used. The final stage of kiln-drying is generally conducted at a humidity somewhat below the actual humidity that on long exposure would produce the same average moisture condition. This is done in order to hasten the drying and to make it uniform throughout each piece.

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# UNITED STATES DEPARTMENT OF AGRICULTURE



## BULLETIN No. 553

Contribution from the Bureau of Entomology  
L. O. HOWARD, Chief



Washington, D. C.

August 10, 1917

### THE CHICKEN MITE:<sup>1</sup> ITS LIFE HISTORY AND HABITS.

By H. P. Wood, *Entomological Assistant, Insects Affecting Health of Animals, Bureau of Entomology.*

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In the present bulletin no attempt has been made to give an exhaustive study of the life history of the chicken mite; rather the aim has been to work out the main points in the life cycle of this pest and to discover principles upon which combative<sup>2</sup> measures may be based.<sup>3</sup>

#### REARING METHODS USED IN LIFE-HISTORY EXPERIMENTS.

The method of feeding the mites was simple. A large earthen jar, in which a small roost was put, was utilized for a breeding cage. The jar was set in a pan of water in order to prevent the escape of the mites, and a coarse-mesh wire screen was fastened over the top to hold the chicken in the jar. When it was desired to feed the mites they were either dropped in the bottom of the jar or else put on the fowl's back. Easy access was thus obtained to the host, and seldom if ever were hungry mites seen in the jar after being one night with the chicken. Sheets of paper were put in the bottom of the jar to collect the manure and some of the mites. Most of the fed mites were found about the roost in cracks prepared for them.

<sup>1</sup> *Dermanyssus gallinae* Redi.

<sup>2</sup> See Farmer's Bulletin No. 801, United States Department of Agriculture.

<sup>3</sup> To Mr. F. C. Bishopp the writer wishes to express appreciation for direction and helpful suggestions obtained in the course of the work.



Molting, mating, and deposition took place in tubes or small vials. In case individuals were being watched, vials were used, and where many mites were confined, test tubes were used. The vials were plugged with absorbent cotton covered with a small piece of black cloth. Black cloth was used because, owing to the contrast in color, it was much easier to observe the small white eggs and larvæ. The test tubes were plugged with cotton covered with white cheesecloth. No moisture or food of any sort was added to the tubes.

In the longevity experiments varied conditions were supplied. Some of the mites were kept in tubes on moist sand, others were kept in dry tubes, and others were on roosts. In the longevity experiment, in which the mites were supplied with a hen's egg, the egg was in a lantern chimney, both ends of which were covered with a piece of black cloth.

### LIFE HISTORY.

#### THE EGG.

In appearance the egg of the mite is a small, oval, smooth, pearly white, and somewhat iridescent object (Pl. I). Ten eggs measured showed a maximum length of 387 microns, a minimum of 373 microns, a maximum width of 265.5 microns, and a minimum width of 244 microns, the average length being 379.3 microns and the average width 255.65 microns.

Incubation during the latter part of August took place in about 48 hours. The average mean temperature at this time was 78.43° F.

#### THE LARVA.

The young larva (Pl. I) on hatching is white and has only three pairs of legs. At the rear of the abdomen is a small protuberance which does not appear on any other stage. The larva moves about slowly, unlike the other stages, which are very active. The length and width of the larval body measure practically the same as those of the eggs. Without ever having fed, the larvæ molt to nymphs. Molting takes place in about 24.5 hours after hatching, when the average mean temperature is 73.5° F.

#### THE FIRST-STAGE NYMPH.

The young nymph (Pl. I) backs out of its larval skin like a person drawing his hand out of a tight glove. It has now acquired another pair of legs, making four pairs. After a few hours of resting, to give time for the body integument to harden, it becomes very active and will now feed if given a chance. The first-stage nymph is slightly darker in color than the larva, having a brownish tinge.

With its long, piercing mouth parts the nymph sucks the blood of the fowl. It crawls from the fowl onto the roost when fully

engorged, and is now bright red, owing to the ingested blood showing through the skin. The measurements of the mite (average of five) at this stage are: Length, 568 microns (abdomen only); width, 338.4 microns; thickness (average of three), 266 microns. After a period of somewhat less than 24 hours the first-stage nymph molts to the second stage. The average mean temperature during the period when the molting was observed was 82.9° F.

#### THE SECOND-STAGE NYMPH.

The second-stage nymph, like the preceding stage, requires a short period of rest to harden the integument. As soon as the nymph becomes active it is ready to feed. Some authors have said that the mite takes long periods of rest. The writer finds that when such rest periods are taken it is from force of circumstances and not from desire on the part of the mite. The mite before feeding measures (average of four) 538.2 microns in length and 297.9 microns in width. After feeding, the mite measures 751.9 microns in length by 461.4 microns in width (average of 10). The second-stage

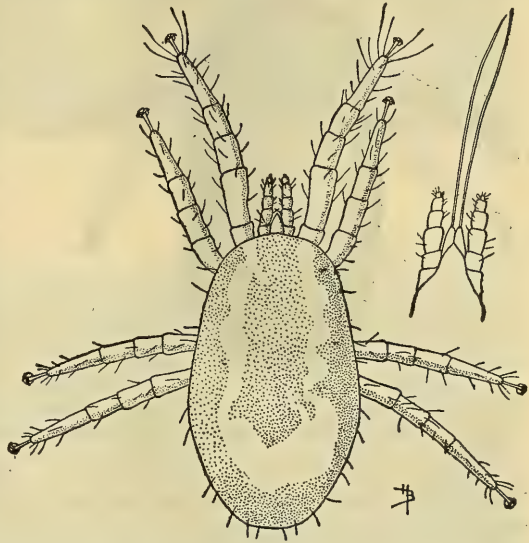


FIG. 1.—The chicken mite (*Dermanyssus gallinae*): Female mite before engorgement. Greatly enlarged. (Bishopp and Wood.)

nymphs molt to adults (fig. 1). This is the rule, although there may be some nymphs which undergo an additional molt before reaching the adult stage. The writer found one mite which apparently had three nymphal stages. A single instance, however, can hardly be accepted as sufficient evidence for making an exception to the rule.

#### THE ADULT.

As soon as the males crawl out of their nymphal skin they rest a short time, and are then ready to reproduce. They may clasp a nymph if no females have yet appeared, but as soon as a female appears a male will find her and clasp her, the venter of the female in close contact with the venter of the male. It is certain that

fertilization can take place soon after molting and before feeding, and it can take place also after feeding. Directly after molting the females will feed, but the males will not. No doubt each male is able to fertilize several females, so that immediately after molt-

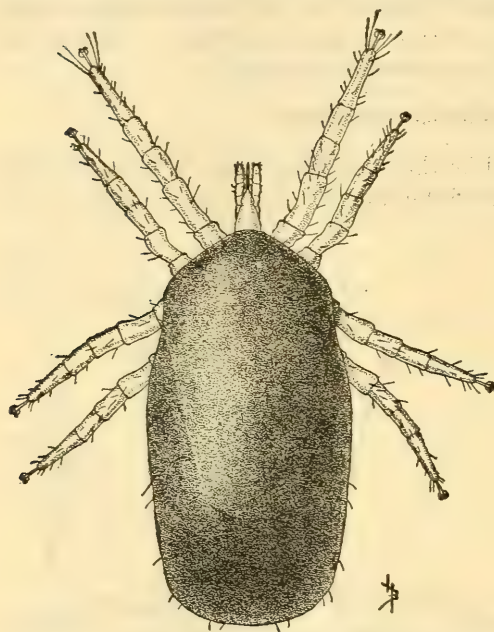


FIG. 2.—The chicken mite: Female mite engorged with blood. Greatly enlarged. (Bishopp and Wood.)

ing this is all the male desires. Normally fertilization takes place off the host, though it is conceivable that occasionally it may take place on the host. The females begin depositing eggs within about 12 hours after feeding. They will feed and deposit fertile eggs repeatedly with only one fertilization. Under observation this was done eight times. No doubt under natural conditions these females would have been visited by males several times. A single feeding during warm weather is all that is necessary for each deposition. A very small number of mites

failed to oviposit after having had one good feeding. An engorged female is shown in figure 2.

### LIFE-CYCLE EXPERIMENTS.

The following outline gives an accurate record of the life cycle as worked out at Dallas, Tex.:

#### First-stage nymph engorgement:

August 6, 6 p. m. Several hundred first-stage nymphs put in jar with fowl.

August 7, 9 a. m. 542 engorged first-stage nymphs recovered.

#### First-stage nymph molting:

August 8, 7.30 a. m. Many have molted to second-stage nymphs.

#### Second-stage nymph engorgement:

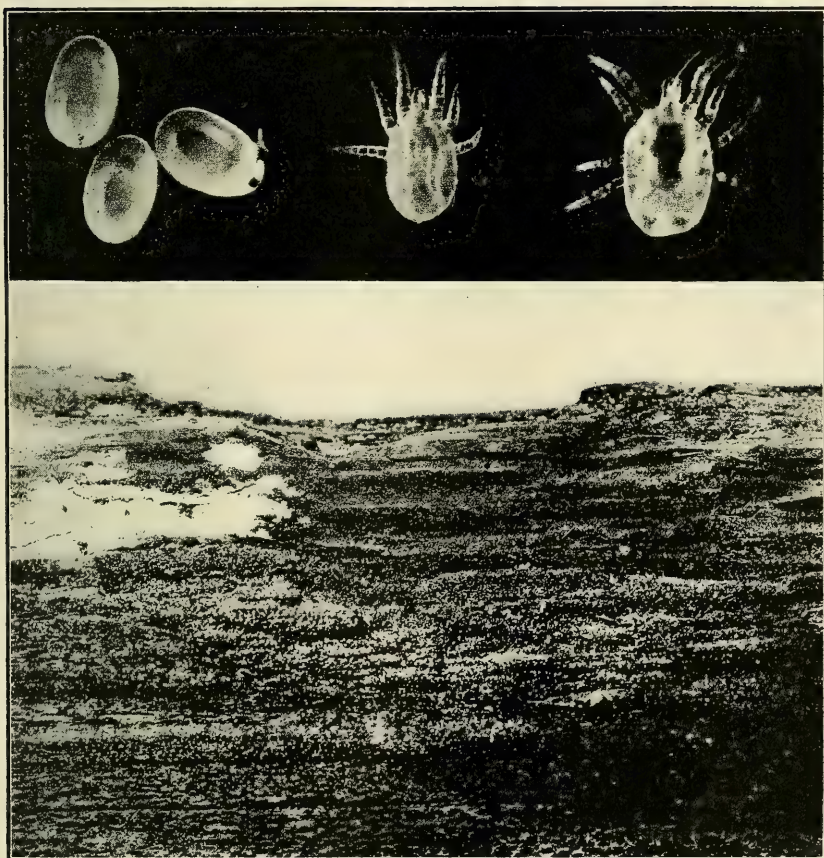
August 9, 5.30 p. m. All the second-stage nymphs (perhaps 50 of the 542 died) put in jar with chicken. The nymphs are very active.

August 10, 9 a. m. 263 engorged nymphs recovered.

#### Second-stage nymph molting and mating:

August 11, 9 a. m. Many have molted. Several pairs found to be in position of copulation.





**THE CHICKEN MITE (*DERMANYSSUS GALLINAE*).**

Upper left, eggs; upper center, larva, dorsal view; upper right, first-stage nymph before feeding; below, old roost showing spots of excrement. All much enlarged except the lower figure, which is somewhat reduced. (Original.)



## First engorgement of females:

August 12, p. m. Put foregoing mites with fowl over night.

August 13, 9 a. m. 70 engorged females recovered, and about 30 unfed males. Females put in separate tubes from the males and one female in a tube.

## First deposition of females:

August 13, 7 p. m. (before). Two females have begun to deposit.

August 14, 9 a. m. Five females are now depositing.

August 14, 9 a. m. Five females are now depositing.

August 15, 8.30 a. m. 52 females are now depositing.

August 15, 1.30 p. m. 61 females are now depositing.

August 15, 5 p. m. Same.

August 16, 10.30 a. m. 62 females are now depositing.

August 16, 4 p. m. 64 females are now depositing.

## Hatching of eggs to larvæ:

August 16, 10.30 a. m. Some eggs from 17 of the females have hatched.

August 17, 11 a. m. 40 females now have eggs hatching.

August 17, 4 p. m. 43 females now have eggs hatching.

August 18, 10 a. m. 48 females now have eggs hatching.

(Sixteen females unaccounted for in notes.)

## Molting of larvæ to first-stage nymphs:

August 16, 10.30 a. m. Some of one female's larval progeny have molted to first-stage nymphs.

August 17, 11 a. m. Some of 34 females' larval progeny now have molted to nymphs.

August 17, 5 p. m. Some of 42 females' larval progeny now have molted to nymphs.

August 18. Some of 57 females' larval progeny now have molted to nymphs.

## Second engorgement of females:

(No males put with females before, during, or after feeding.)

August 20 (night of). About 60 females put with fowl.

August 21, 9 a. m. 59 engorged females recovered and put in separate vials, except seven which were not fully fed.

## Second deposition:

August 22, 5 p. m.—

6 females have laid 1 egg each.

5 females have laid 2 eggs each.

24 females have laid 3 eggs each.

10 females have laid 4 eggs each.

6 females have laid 5 eggs each.

2 females have laid 6 eggs each.

August 23, 9.30 a. m.—

6 females have laid 1 egg each.

4 females have laid 2 eggs each.

10 females have laid 3 eggs each.

15 females have laid 4 eggs each.

11 females have laid 5 eggs each.

5 females have laid 6 eggs each.

2 females have laid 7 eggs each.

Totals, 53 females deposited 203 eggs.

The average mean temperature during this period was 80.8° F. No more eggs were deposited by these females until they were fed again. Two of the mites died after this deposition.



#### Hatching and larva molting from second deposition:

On August 23, 10 a. m., 13 eggs of this lot had hatched and one of the larvæ already had molted to a nymph. On August 24, 3 p. m., 178 eggs had hatched, and 66 of the resulting larvæ had molted. August 25, 2 p. m., all but four eggs had hatched, and 167 of the larvæ had transformed to nymphs. The following day only three eggs remained unhatched, and 190 of the 200 larvæ hatched had become nymphs.

#### Third engorgement:

August 26, 5 p. m., 51 females were put on a fowl for their third feeding; 49 of these were recovered on the following morning. All of these were engorged except one.

#### Third deposition:

Three of these females had begun depositing at 11 a. m., August 27. During the afternoon, night, and following day deposition proceeded freely. All but eight of the females had begun depositing at 5 p. m., August 27. All except 25 had completed deposition at 7 p. m., August 28. Only one egg was found after 4 p. m., August 29. It will be seen that deposition began approximately 18 hours after the mites were placed on the host and that practically all the eggs were deposited during the two days following the night of engorgement. The average mean temperature during this period was 78.43° F.

#### Hatching and larval molting from third deposition:

Two of these eggs had hatched by 8 a. m., August 29. All of those which completed incubation had hatched by 3 p. m. on August 31 except one, which hatched prior to 2.30 p. m. the following day. All but three eggs hatched, or slightly less than 1.3 per cent.

In a series of 10 eggs of the foregoing lot deposited between 2 and 4 p. m., August 27, six hatched between 8 a. m. and 3 p. m., August 29. Two others hatched during the next hour, and all were hatched at 10 the following morning. In another series of ten eggs deposited on August 27, the incubation period ranged from 45 to 49 hours, with an average of slightly less than 48 hours. During this period the average daily mean temperature was 78.43° F.

Molting of the larvæ which hatched on August 29 to September 1 from the eggs of the third deposition began on August 30, at 10 a. m., and was complete, with the exception of one individual, at 4 p. m., on September 2. The molting of the 10 larvæ hatched on August 29 was observed and ranged from 19 to 28 hours, with an average of 24.5 hours.

#### Fourth engorgement and deposition:

On the evening of September 3 the 46 remaining females were placed with a fowl for their fourth feeding. Thirty-five engorged females were recovered the following morning. On September 6 deposition was completed by all but two females. On September 8 all had finished depositing. One died without ovipositing, and three died soon after deposition was complete.

#### Fifth engorgement and deposition:

The remaining 32 females were put on a host for the fifth time on the evening of September 8. No males had been with them since previous to the first feeding. On September 9 22 engorged females were recovered, and all but two deposited—one of these died.

#### Sixth engorgement and deposition:

The sixth engorgement of the 20 females was made during the night of September 13. Fifteen of these were found engorged the following morning. Of these, three failed to deposit eggs. One of these three died.

## Seventh engorgement and deposition:

During the night of September 17 12 females were placed with a host and 10 recovered. Seven of these deposited, one of the other three died, and one died soon after deposition.

## Eighth engorgement and deposition:

The eighth engorgement was made during the night of September 22. All of the eight females applied to the host were engorged. Six of these deposited, beginning September 23 and finishing September 26. One female died without depositing and one failed to deposit.

On September 28, 100 per cent of the eggs deposited following the eighth engorgement had reached the nymphal stage, thus showing that fertility persisted though males were not with them since prior to the first feeding.

## Ninth engorgement:

On September 28 the seven remaining females were put on a host for the ninth engorgement, but as only one was recovered the following morning the experiment was discontinued.

A summary of the depositions, with the number of eggs deposited by each female, is given in Table I.

TABLE I.—Summary of oviposition records of *Dermanyssus gallinae*, Dallas, Tex., 1916.

| Depositions.             | Number of females depositing 0 to 8 eggs each. |   |   |    |    |    |    |   |   | Total number of eggs. | Average per female. | Number of females depositing. | Number of females engorged. |
|--------------------------|------------------------------------------------|---|---|----|----|----|----|---|---|-----------------------|---------------------|-------------------------------|-----------------------------|
|                          | 0                                              | 1 | 2 | 3  | 4  | 5  | 6  | 7 | 8 |                       |                     |                               |                             |
| First <sup>1</sup> ..... |                                                |   |   |    |    |    |    |   |   |                       |                     |                               |                             |
| Second.....              | 0                                              | 6 | 4 | 11 | 14 | 11 | 4  | 3 | 0 | 203                   | 3.8                 | 53                            | 53                          |
| Third.....               | 1                                              | 2 | 1 | 2  | 11 | 14 | 11 | 7 | 0 | 239                   | 4.98                | 48                            | 49                          |
| Fourth.....              | 2                                              | 0 | 2 | 3  | 10 | 6  | 9  | 1 | 2 | 160                   | 4.84                | 33                            | 35                          |
| Fifth.....               | 2                                              | 0 | 0 | 4  | 5  | 5  | 5  | 1 | 0 | 94                    | 4.7                 | 20                            | 22                          |
| Sixth.....               | 3                                              | 1 | 0 | 5  | 2  | 1  | 2  | 1 | 0 | 48                    | 4.0                 | 12                            | 15                          |
| Seventh.....             | 3                                              | 0 | 4 | 1  | 0  | 1  | 1  | 0 | 0 | 22                    | 3.14                | 7                             | 10                          |
| Eighth.....              | 2                                              | 0 | 1 | 1  | 2  | 1  | 0  | 1 | 0 | 25                    | 4.16                | 6                             | 8                           |

<sup>1</sup> Not recorded.

## DISCUSSION OF RESULTS OF LIFE-CYCLE EXPERIMENTS.

No attempt was made in the experiment to see how quickly the life cycle could be accomplished. In the foregoing experiment the actual time taken for the mite to pass through its life stages was 10 days. Under natural conditions in August without doubt this time would be reduced to at least 8½ days. Tables II and III show in brief the actual time taken in the experiment and the probable time in nature.

TABLE II—*Actual time taken by the mite (Dermanyssus gallinae) in experiment to go through life cycle.*

| Date.  | Hour.                        | Day. | Stage of development.                                                          |
|--------|------------------------------|------|--------------------------------------------------------------------------------|
| Aug. 6 | { 9 p. m. ...<br>9 a. m. ... | 1    | { First-stage nymphs fed on fowl.<br>First-stage nymphs are all fed.           |
| 7      | { 9 p. m. ...<br>9 a. m. ... | 2    | Second-stage nymphs molted from first-stage nymphs.                            |
| 8      | { 9 p. m. ...<br>9 a. m. ... | 3    |                                                                                |
| 9      | { 9 p. m. ...<br>9 a. m. ... | 4    | { Second-stage nymphs fed on fowl.<br>Second-stage nymphs recovered fully fed. |
| 10     | { 9 p. m. ...<br>9 a. m. ... | 5    | Adults have molted from second-stage nymphs.                                   |
| 11     | { 9 p. m. ...<br>9 a. m. ... | 6    |                                                                                |
| 12     | { 9 p. m. ...<br>9 a. m. ... | 7    | { Females fed on fowl.<br>Females fully fed recovered.                         |
| 13     | { 9 p. m. ...<br>9 a. m. ... | 8    | Eggs being deposited.                                                          |
| 14     | { 9 p. m. ...<br>9 a. m. ... | 9    |                                                                                |
| 15     | { 9 p. m. ...<br>9 a. m. ... | 10   | { Some eggs still being deposited.<br>Some eggs have begun to hatch to larvæ.  |
| 16     | 9 p. m. ...                  | 11   | Larvæ have begun to molt to first-stage nymphs.                                |

TABLE III—*Probable time in nature the mite (Dermanyssus gallinae) takes to go through life cycle.*

| Day.       | Hour.                      | Stage of development.                                         |
|------------|----------------------------|---------------------------------------------------------------|
| First..... | { a. m. ....<br>p. m. .... | Eggs laid.                                                    |
| Second...  | { a. m. ....<br>p. m. .... |                                                               |
| Third..... | { a. m. ....<br>p. m. .... | Eggs hatched to larvæ.                                        |
| Fourth...  | { a. m. ....<br>p. m. .... | Larvæ molt to first-stage nymphs.<br>First-stage nymphs feed. |
| Fifth..... | { a. m. ....<br>p. m. .... | First-stage nymphs are molted to second-stage nymphs.         |
| Sixth....  | { a. m. ....<br>p. m. .... | Second-stage nymphs feed.                                     |
| Seventh..  | { a. m. ....<br>p. m. .... | Second-stage nymphs molt to adults.                           |
| Eighth...  | { a. m. ....<br>p. m. .... | Females feed.                                                 |
| Ninth....  | a. m. ....                 | Eggs laid.                                                    |

The average rate of deposition is about four eggs per day; that is, one egg in about 6.4 hours.

The rapidity with which the mite may reproduce is amazing. The possible progeny of one female in five weeks is conservatively estimated at 1,631 individuals, or, considering the duration of life of a female as eight weeks, her progeny would total 2,609 mites.

#### LONGEVITY.

As might be expected, since it feeds often and ordinarily does not have to wait long for a host, as do many of the ticks, the mite lives a comparatively short time in the absence of food. The experiments indicate that a certain amount of moisture and moderate temperature favor longevity, while extreme dryness and high temperatures are unfavorable factors. The mites die off much faster in the absence of food during the hot summer months than they do during the



winter. The lowest temperature experienced by any of the mites under observation was 15° F., the highest 97.5° F. Adults and second-stage nymphs, during the months of July, August, September, and October, lived longest when moisture was applied—from 91 to 98 days. Under dry conditions the mites lived 56 to 85 days. During the months of August, September, October, November, and December mites under dry conditions lived from 100 to 108 days. The longest that adults which had never fed as adults lived was from 88 to 96 days; this was during the months of October, November, December, and January. All stages on a stick of wood lived 91 to 113 days in the months of September to January, inclusive. All stages in a glass chimney with a cracked egg lived more than 107 days during the same months.

First-stage nymphs have about the same period of longevity as the other stages. During the months of July to November, inclusive, this stage, when moisture was added, exhibited a longevity of 81 days under both moist and dry conditions. Second-stage nymphs seem to be the longest lived. During the months of September to January, inclusive, individuals in this stage lived 139 days. Females which had completed oviposition lived from 29 to 39 days during September and October, when kept under dry conditions. Females feeding and depositing continuously live longer than those not allowed so to feed and deposit. In the life-cycle experiment some females lived longer than 53 days.

One may therefore conclude that the mite can be starved out of a chicken house by keeping fowls and other animals away from the house for four months during the summer season and five months during the cooler season. It is probable that with uniformly cold weather, as in the Northern States, the longevity would be somewhat greater than in these experiments, all of which were conducted at Dallas, Tex.

## FEEDING AND HIDING HABITS OF MITES.

### FEEDING HABITS.

The usual habit of the mite is to feed at night. An experiment was conducted to determine whether mites feed and leave the fowl immediately or whether they have a particular time for dropping, such as just before daylight, as one writer claims. Two hours before dark a fowl was put on a roost containing a large number of hungry mites. Very few mites ventured far out of their hiding places at this time. A few did go to the fowl. At dark, two hours later, only four mites were found to have fed and left the fowl. One hour after dark nearly 600 mites (adults and first and second stage nymphs) had fed and left the fowl. One and a quarter hours later 535 more fed mites left the bird. Mites continued to drop in smaller numbers until after

daylight. The writer finds that normal feeding takes place during the hours of darkness and that mites leave the fowl soon after feeding. All stages of mites will go on a fowl, feed, and leave it in less than two hours. In another experiment from 20 minutes to one-half hour was found to be sufficient time for complete engorgement. In one experiment about 30 per cent of a large number of mites put on a fowl in an earthen jar at 10 a. m. were full fed when observed at 2 p. m. The fact that some mites will feed day or night accounts in part for their very rapid increase about a sitting hen.

Though mites feed at night, they do not necessarily all crawl off the host before the fowls leave the roost. Both fed and unfed mites may be retained in the feathers when the fowls are running about. The number of such mites on a fowl seems to be small, but quite sufficient to infest a new place. The length of time mites may remain on a fowl after it has been on an infested roost is not certain. Experiments designed to throw some light on this point developed that nearly all mites leave the fowl by the end of the third night, but a few stragglers may persist for several days. It would be advisable for a person introducing new stock into his mite-free flock to use a little caution if he would avoid an infestation.

The author would suggest that new stock not known to be free of mites be allowed to roost the first few nights on a new roost wrapped with pieces of folded paper, preferably black. The object of using the paper is to furnish a convenient place for mites to hide. The paper may be examined, and if mites are found the fowls should be kept on this roost five or six days, or until no more mites come off of the fowls. If mites are discovered, by removing and destroying the papers and treating the roost thoroughly with kerosene or crude oil any danger of the mites getting back on the fowls can be avoided.

The ease with which mites reach the host has a decided bearing on the rapidity of increase. Hungry mites, though placed quite near a fowl, have great difficulty in finding the host unless the means of access is direct. This fact would account for the mite preferring to hide on the roost. When mites are found all over the walls the infestation must be a heavy one. To apply the above facts to aid in control work, the roosts should not be connected up with the walls of the chicken house unless some method of preventing the access of the mite to its host is used. The same may be said of the nests. The simpler and more isolated the roosts and nests, the easier it will be to eradicate the mite. (For control measures see Farmers' Bulletin 801.)

#### HIDING HABITS.

The direct rays of the sun act as a powerful killing agent when mites are exposed to them. Mites put on a board in the direct sun (July) were killed in a few seconds. Need of a suitable dark, pro-

tected place for deposition and molting governs the hiding habits of the mite. This may be a crack in a board or only a rough place, or it may be in the dry manure or litter. Here a place for deposition, molting, mating, and resting is provided. A very common hiding place for mites is near the nails that hold the roosts to their supports. When the mites become abundant they will overrun the roost and may be found anywhere in the chicken house. Their presence about a house may be detected by the minute black and white spots (excrement) left on the roosts. (See Plate I.) In the spring, when the weather becomes warm, mites come out of their hiding places in great numbers and, not having fed for perhaps a month, run about as tiny gray specks in ravenous haste seeking food. At this season the poultryman can tell easily whether his poultry or coops are infested with mites. A little later, in the case of light infestations, the mites may seem to disappear, but a careful search will show that they have had a feeding of blood and are hiding to reproduce. From now on they come out, perhaps only a few at a time, every night as long as the weather is sufficiently warm. It is important to clear away all manure and trash before trying to kill the mite by spraying with insecticides and to have a roost which may be removed easily, so that the underside may be sprayed.

#### PASSING THE WINTER.

For the mite the winter season is merely a time of lessened activity. During warm spells and in artificially heated houses the mite will feed if fowls are in reach. Since the mite may live at least four or five months, as shown by longevity experiments, there is no chance in the Southern States of cold weather lasting so long that the mite will starve from this cause. Low temperatures may kill the weaker individuals but do not destroy those with more vitality.

#### ENEMIES.

A small black ant (*Monomorium minimum* Buckley) has been seen to carry away recently-fed mites. Other species, notably the fire ant (*Solenopsis geminata* Fab.), destroy many. Certain spiders also have been seen to attack and destroy mites. Whether or not ants and spiders are of much importance in this respect is not definitely known. The author has found, however, that some infestations which were not quite killed out by spraying seemed to be exterminated by natural enemies.

#### DISPERSION.

Mites may be spread in the following ways:

- (1) By infested fowls transferred to clean localities.
- (2) By the use of boxes and crates in which infested fowls have been kept.



(3) Through the carrying by man of mites on his clothing, thereby starting an infestation.

(4) Through the carrying of mites by sparrows, and probably by pigeons, from one place to another in their feathers.

(5) By horses, cattle, dogs and cats, and certain wild animals, such as foxes, skunks, and weasels, which possibly act as mechanical carriers.

(6) By migration of the mites to buildings in contact or close proximity to infested premises.

The most important method of spread, without doubt, is by infested fowls. In general, it may be said that any carrier may become of greater or less importance, depending upon its closeness of association with an infestation and the degree of the infestation. Also, the danger of infestation increases the nearer clean fowls are located to infested ones.

#### OTHER HOSTS.

The writer has had thousands of mites crawling on his skin but has no knowledge of having been bitten by any of them; the feeling produced by the crawling mites, however, is very disagreeable. Other people testify that the mite bites them. While turkeys are attacked freely, chickens are favored, and other poultry (pigeons) are fed upon. Stock in barns abutting on chicken houses are at least irritated by mites.

#### FOOD OTHER THAN BLOOD.

Does the mite feed on anything besides blood? Inasmuch as a number of writers have said that the mite feeds on filth of different sorts, a few experiments were undertaken to get some evidence on the question.

Mites in different stages were put with moist and dry hen droppings, and with feed such as cornmeal and bran, and were watched closely for several days. Mites were then tried with white of egg and yolk of egg; a small quantity being put in a tube with about 50 mites. The mites did not appear to feed, nor, after several days, did they look as if they had fed on any of these substances. Mites were put in a vessel with a partially dried egg but did not appear to feed on it. Mites with access to filth, dirt, etc., lived no longer than mites without access to these substances, and they did not breed in this material.

Inasmuch as the mouth parts of the mite are fitted for piercing and sucking, a fresh egg was cracked so as to expose the amnion, to see if the mite would be able to draw nourishment from it. Careful

measurements were made before and after the chance to feed on egg was offered the mites, but there was practically no change except in the case of one female which increased in length 71.75 microns and in width 100.45 microns. Some of the same mites which refused to feed on the cracked egg fed on a fowl when the chance was given them. The experiment indicates that mites rarely take nourishment in this way.

#### CONDITIONS FAVORABLE FOR PROPAGATION OF MITES.

The two conditions most favorable for the propagation of mites are (1) frequent direct and easy access to the fowls, and (2) numerous hiding places, such as a complicated roost, dirt, litter, etc. Other favorable conditions are the allowing of dirt and refuse to collect without removal for several weeks. Darkness and dampness without doubt help the mite to live longer in the absence of food. Even under the most sanitary conditions it is able to increase and multiply, so that cleanliness alone is not sufficient to rid premises of the mite, although it is one of the first things to be sought when an attempt at extermination is made because of the greater effectiveness of insecticides when applied.

#### SUMMARY OF LIFE HISTORY.

Blood is the necessary food of the mite in all stages except the larva, in which stage no food is taken.

It takes about one-half hour to one hour for the mite to get its full feeding and leave the fowl. The mite ordinarily crawls off the fowl onto the roost or other near-by place, where it finds a convenient crack or crevice in which oviposition, molting, and mating take place. Females deposit an average of four eggs each at the rate of four eggs in 24 hours. After finishing deposition the females feed again, usually at night, one engorgement nearly always being sufficient for each deposition. When full of blood the female is elliptical in outline, plump, and blood red (see fig. 2). Females will continue to feed and deposit eight times at least, and possibly many more times. The female must copulate at least once before she will deposit fertile eggs, although fertilization is not necessary before each deposition. The male does not feed immediately upon molting as does the female, but stays in the cracks, no doubt to fertilize several females. The proportion of males to females is about one to two. The eggs hatch in two days (August). The larvæ, which have only three pairs of legs, molt without feeding in about one day. The first meal is taken as a first-stage nymph. The first-stage nymph before feeding is light colored, like the larva, but is much more active. It becomes engorged

with blood once and is ready to molt. One and one-half days is the length of time required by this stage. The second-stage nymph before feeding is rather grayish and, like the preceding stage, is active. With one meal of blood and a molt the second-stage nymph becomes adult. The second-stage nymph, when fed, appears much like the adult (see fig. 2), but smaller. All stages after feeding are blood red. One and one-half days is required to bring the second-stage nymph to the adult. Unfed females are slightly larger than unfed males. Mites that do not get a chance to feed may live four or five months.



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BULLETIN No. 554



Contribution from the Bureau of Entomology  
L. O. HOWARD, Chief

Washington, D. C.



September 21, 1917

THE CRANBERRY GIRDLER.<sup>1</sup>

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IMPORTANCE OF THE PEST.

The severity of the attacks of the cranberry girdler (*Crambus hortuellus* Hübner) upon cranberry vines, together with its general distribution throughout the cranberry-producing regions of the United States, marks this pest as one of prime importance to this industry.

The investigations into the seasonal history of the girdler and the observations on various methods employed to control it were made in New Jersey throughout a period covering nearly four years.<sup>2</sup>

Bog-management practices in New Jersey are diverse, and many opportunities have been offered to note the effects on cranberry-girdler infestations following one practice or another. Although it was stated by Smith (9, p. 21-24)<sup>3</sup> in 1903 that there is no such destruction of large tracts in New Jersey as in Massachusetts, it is apparent at this time that the girdler has become more of a pest each

<sup>1</sup> *Crambus hortuellus*; order Lepidoptera, family Pyralidae, subfamily Crambinae.

<sup>2</sup> During the field seasons of 1914 and 1915 the writer was assisted by Mr. H. K. Plank, of the Bureau of Entomology, and opportunity is here taken to acknowledge Mr. Plank's services, particularly in the field of insect photography. The work has been under the general supervision of Dr. A. L. Quaintance, Entomologist in Charge of Deciduous Fruit Insect Investigations, Bureau of Entomology.

<sup>3</sup> Reference is made by number to "Literature cited," p. 19.



year. Smith's statement no longer holds true for New Jersey bogs, owing to the fact that many large areas of cranberry vines have been utterly destroyed by the insect in recent years.

Owing to its habit of feeding concealed in trash under the vines, the worm is very difficult to find and has been overlooked by many growers who were aware of the injury but uncertain as to the cause.

### HISTORY.

The cranberry girdler has figured in entomological writings as a pest of grasses and will be found referred to in that connection as the "garden crambid" or "garden veneer." In cranberry districts it is frequently spoken of as the "girdle worm," but the generally accepted name for the species is the "cranberry girdler."

From the time of its description by Hübner (1, p. 29, pl. 7, figs. 45, 46) in Europe until the work of Scudder (5) and of Felt (6, p. 75-76, 87-88, 99-100; fig. 7; pl. 3, fig. 19; pl. 9, fig. 19; pl. 14, fig. 19) little was known of its habits. The American form was first described by Zeller (3, p. 155-156) under the name of *Crambus topiarius*, and later by Grote (4, p. 74), who stated that Zeller considered *topiarius* to represent the European *hortuellus* in the American fauna. Of late years the girdler has been the subject of considerable study in Massachusetts by Franklin (10, p. 7-8).

### DISTRIBUTION.

This pest is not confined to the cranberry-growing sections, but is widespread throughout the United States, Europe, and Canada. Originally described as a European species, it is listed by Wood (2, p. 216, pl. 47, fig. 1497, *n*) from various parts of England and by Felt (6, p. 99) from St. John, New Brunswick, Canada. Felt gives the distribution as Maine, Massachusetts, North Carolina, Illinois, Nevada, and California, from which it may be noted that the species occurs practically from one end of this country to the other, and it is probable that it will be recorded eventually from every State in the Union. In the cranberry districts of Massachusetts and New Jersey it is very abundant, and in New Jersey especially it may be said that the majority of bogs show more or less injury by this species. It is common in Wisconsin, but has not become a serious cranberry pest, probably because the bog floors, as a rule, are kept wetter than those in the eastern cranberry States.

### FOOD PLANTS.

The early records mention this insect as having been found commonly on grasses, but just what grasses is not specified. Fernald (7,

p. 40, fig. 1) gives sheep sorrel as a host. In later years cranberry is mentioned frequently. On cranberry the larvæ confine their feeding to the woody parts, such as the runners and the larger roots, and occasionally some of the finer roots are taken.

The investigation in New Jersey shows that a sedge, commonly called "three square" (*Scirpus americanus*), is fed upon liberally when present in cranberry bogs. This is one of the abundant bog weeds, and the larvæ attack it at the crown, sometimes forming their cocoons in this situation.

### FEEDING HABITS AND DESTRUCTIVENESS.

All the injury is done during the larva stage, beginning in early June and continuing throughout the summer and fall until about mid-October. The worms are slow of growth, and the dying of the vines can not be detected readily until late August or September. During the early part of the season the worms are small and feeding is not extensive, but in late summer, when the worms are nearly full grown, they are ravenous feeders, and the lessened vitality of the vines is evidenced by the appearance of the foliage, which becomes fiery red or brown in September and October. Large quantities of the leaves drop off, and the few which remain on completely girdled vines become dry and drop during the winter, leaving areas of dead vines denuded of foliage presented to the view the following summer. Such dead areas may vary in size from a square foot to spots containing many square rods. At the close of a second year of infestation many of these dead areas will become merged, owing to the dying out of the vines in the intervening areas, by further girdler feeding. Under such conditions it is common to find areas of dead vines, leafless and very conspicuous by their black color, comprising as much as one-half acre (Pl. I). Usually the vines around the margins of the dead areas die back a little farther each succeeding year, although if the work of the girdler ceases, runners may spread out over the dead vines and tend to re-cover the area. This, however, is a very slow process, involving several years, and in the meantime the spot very frequently becomes a verdant patch of grass or sedge. In certain bogs small areas 2 or 3 feet in diameter (Pl. II, A) may be killed, particularly where the trash is very thick beneath the vines, as is likely to be the case in some of the corners, and the damage will not grow to alarming proportions. Such areas vary little in appearance from year to year until at some time the girdlers are exterminated, perhaps by a prolonged flooding of the bog. Then the runners push out and eventually fill in the bare spaces.

Where girdler feeding has not been severe enough completely to kill the vines, and even in those places where only slight gnawing

of the runners has occurred, in a number of bogs it has been noted that such areas develop more rotten fruit than do adjacent vines in healthy condition. The weakening of the vines apparently tends to make the fruit more susceptible to fungous attack.

In severe cases of girdler feeding the vines may become so loosened, or so badly eaten and severed, that they may be rolled back with slight exertion, exposing the bare trash beneath.

Girdled vines are often found on which injured portions, where the bark has been abraded, are covered with white cottony material; these are the waxy coverings of mealy bugs (*Pseudococcus adonidum* L.), and as they are rarely found on healthy vines they should be classed as secondary pests.

The specific injury caused by the feeding worms is due to their eating through the bark of the runners into the wood, which often occurs to such an extent that the runner is completely severed. (Pl. III, A, B.) Gnawing the bark completely around a runner will also kill that part of the plant beyond, provided no other roots nourish this part. Runners are often seen which have been tunnelled for short distances by this insect, and some are eaten down to mere splinters. The fine roots as well are eaten, but to a less extent than is the woody part. Feeding marks are sometimes found on the crowns of the plants where they arise from the hills as originally set. Practically all of the feeding, however, is done by the larvæ in a concealed position—in the trash which is found beneath the vines, which consists largely of fallen leaves, pieces of vines, and other débris, and forms a mat over the runners, affording the girdlers excellent protection from parasitic insects.

The feeding marks of the cranberry girdler should not be confused with those of the cranberry rootworm (*Rhabdopterus picipes* Oliv.), which feeds on the small roots and root hairs and on the runners only to the extent of eating the bark, usually on the side which touches the ground. In general, the rootworm feeds below the surface of the ground, whereas the girdler feeds above the surface but hidden in a layer of trash. The excrement of the girdler in badly injured areas is very abundant, appearing in masses, which indicates that the larva feeds for a considerable length of time without materially changing its location. Often the excrement, intermixed with bits of trash, will be found with silken threads woven loosely through it, and these rude galleries probably constitute a protective covering for the worm during the feeding period. Scudder (5) figured a cylindrical, upright case for this larva occurring on grasses, and Fernald (8, p. 150) speaks of a vertical tube, constructed of bits of vegetable material held together by silk, but neither of these larval cases has been found on New Jersey cranberry bogs, and for this reason the larvæ are described as being naked.



## DESCRIPTION OF THE CRANBERRY GIRDLER.

## THE EGG.

The egg (Pl. IV, *D*) is white when first laid, becoming more and more pinkish as hatching time approaches. It is oval in outline, broadly rounded at the ends, with the end through which hatching occurs slightly more tapering than the base. The apex is divided into a number of cells of various patterns. The sides are ribbed vertically, usually regularly, but not always. These are crossed longitudinally by much finer ribs. The average size of four eggs is as follows: Length, 0.441 mm.; greatest breadth, 0.318 mm. Fifty-eight eggs laid end to end would measure about 1 inch.

## THE LARVA.

The last-stage larva (Pl. IV, *A, B*) has a dark-brown head with ocelli, mandibles, and labrum black; the clypeus is dark brown, the thoracic shield and tip of abdomen light amber, and the rest of the body sooty white, bearing numerous long and short hairs which are black at the base and finely pointed. Its length is 12 to 15 mm., or about one-half inch.

## THE PUPA.

The general color of the pupa (Pl. IV, *C*) is pale yellow with eyes becoming black before the emergence of the moth; the tip of the abdomen is dark brown, the outlines of the wings and the antennæ are brown, and the segments of the abdomen are edged with brown. The length is 8.5 to 11 mm., or about three-eighths of an inch.

## THE ADULT.

Scudder (5) gives the following description of the adult (Pl. V, *A, B*):

Fore-wings above of a pale straw color, growing pale buff apically heavily marked with blackish fuscous of varying shades and with silver; the latter is mostly confined to two subapical cross-bands, the upper half of the inner and the whole of the outer oblique, the inner bent just above the middle and crossing the entire wing (excepting that it fails to reach the costal margin above), the lower half at nearly right angles to the upper half and subparallel to the outer margin; the inner band is bordered interiorly with brown which extends to the costal margin; a broad stripe of silvery gray tapering apically follows the subcostal vein to the end of the cell and four fuscous longitudinal stripes reach nearly or quite to the inner silvery band, the uppermost more or less mingled with buff following the costal edge for nearly a third its length and then running a little obliquely across the upper extremity of the cell, the next tinged with silver so as to become pearl gray extending along the middle of the cell; the other two follow the median and submedian nervures; three other short longitudinal fuscous lines, much overlaid and concealed by silver,

follow the nervules beyond the cell, while a supplementary brownish and oblique line intervenes between the oblique portion of the costal stripe and the inner margining of the inner silvery band; the extreme outer margin of the wing has a black line on the upper half, and on the lower half at the nervule tips three or four black points; the fringe is silvery. Hind-wings uniform silvery gray, narrowly edged on the upper half of the outer border with pale brown, the fringe silvery white. Expanse of fore wings, ♂ 15mm; ♀ 17mm. Described from four bred males.

The average length of 14 specimens, measuring from front of eye to tip of wing when folded, is 9.4 mm., or about three-eighths of an inch. The females are rounder of abdomen and average larger than the males.

#### THE COCOON.

The cocoon is composed of scraps of débris found on the floor of the bog, usually consisting of bits of dead leaves, bark, twigs, fine roots, grasses, sand, and dried excrement of the larva, with now and then a whole leaf attached loosely to the outside. This material is held together by fine strands of white silk, and the interior has a lining of white silk, parchmentlike in texture. In sandy locations the external part of the cocoon is sometimes made entirely of sand. However, for New Jersey bogs the typical cocoon is made of trash and appears dark brown in color.

The shape of the cocoon is variable (Pl. VI, *B.*). In some instances it might be described as resembling in miniature a short-handled Indian club, while others appear of a curved cucumber shape. One end is always broadly rounded, being of greatest diameter about one-third the distance to the smaller end, and tapering to a cylindrical, slightly curved neck. Some loose strands of silk are placed in the neck for protection, but the end is not securely sealed as are the walls. When pupation occurs the pupa lies with head toward the neck, and the moth is able to push its way through, leaving the pupal shell within the cocoon. One can not tell from external appearances whether the moth has emerged, because the exit hole is well concealed by the arrangement of pieces of trash which tend to fall back into position after the passage of the moth. The measurements of 13 cocoons are as follows: Length 11 to 18 mm., average 13.84.; greatest breadth 5.5 to 10 mm., average 6.88 mm.

Vertical cylindrical cases often encountered on cranberry bogs, which might be confused in the mind of the grower with those of the girdler, are those formed by larvæ of caddiceflies—harmless insects which breed in wet places. There are many styles of these caddicefly cases (Pl. VI, *A*), and they are often found projecting straight up through the trash in areas infested by the cranberry girdler.

## SEASONAL HISTORY.

The seasonal-history data were secured on numerous bogs throughout the State of New Jersey and in rearing cages kept in a screened open-air insectary. Four-ounce ointment cans were satisfactory for securing the feeding, cocooning, and pupation data, while for oviposition data and caging the moths a cloth-covered lamp chimney was found to fit tightly over a 1-ounce ointment can.

## ADULT STAGE.

The time of emergence in the spring and summer depends largely upon whether the bog is a dry one or a flowed one and on the date of drawing the winter flowage.

*Dry-bog conditions.*—Cocoons kept at the laboratory during the winter of 1914-15, under approximately dry-bog temperatures, yielded moths from May 11 to June 18. In the cranberry bog where winter flowage was removed on April 10, moths began flying June 7.

*Winter flowage drawn May 10.*—This represents probably the average date at which New Jersey growers remove the winter flowage. From a large mosquito-bar cage placed over an infested area of cranberry vines bared of winter flowage on the 10th of May, adult emergence was noted from June 10 to July 8. The complete record appears in Table I.

TABLE I.—Emergence of cranberry-girdler moths on cranberry bog, Whitesbog, N. J., 1915.

| Date of removal from cage. | Number of moths. | Date of removal from cage. | Number of moths. |
|----------------------------|------------------|----------------------------|------------------|
| June 10.....               | 16               | June 18.....               | 33               |
| June 11.....               | 48               | June 21.....               | 16               |
| June 12.....               | 42               | July 2.....                | 1                |
| June 15.....               | 117              | July 8.....                | 1                |
| June 16.....               | 24               |                            |                  |

Keeping the winter flowage on a bog until some time after May 10, in the region of New Jersey, produces a later emergence of moths. There is a date, however, which no one as yet has determined definitely, when, owing to the lateness of holding the flowage, the immature stage of the moth is killed. One observation was made in 1916 on a bog at Howardville, N. J., showing that, although the winter flowage had been held until July 12, a number of the girdlers in the immature stages were able to survive this treatment, and moths were found flying August 3.

On grassy bogs and on bogs bearing a heavy mat of vines the emergence of the moths may be prolonged over a long period. At



Whitesbog, N. J., records of late-flying moths have been kept for three years, and it is not unusual to find them flying until mid-August. The heavily shaded places, from which the flowage is slow in draining, probably retard the development of the immature forms in the cocoons and thus give rise to later issuing moths. These are the conditions which have led to the erroneous conclusion that more than one brood occurs in the course of a season.

The moths, which are strong fliers, are seldom noted in their concealment among the vines, but when disturbed they fly several rods or more, finally seeking shelter in the vines again and often running down to the trash for security. When resting, the moths fold the wings tightly around the body and are inconspicuous; at night, with the aid of a lantern, they may be seen in this position clinging to vines or the stems of tall grasses.

*Proportion of sexes.*—In the early summer the males and females appear to be about equal in number; for example, on June 11, 24 moths were collected, of which 12 were males and 12 were females. In late summer, however, the males are far in excess of the females, as shown by the following collections: Thirteen moths taken July 27 consisted of 11 males and 2 females, while of 23 moths collected August 10 only 5 were females.

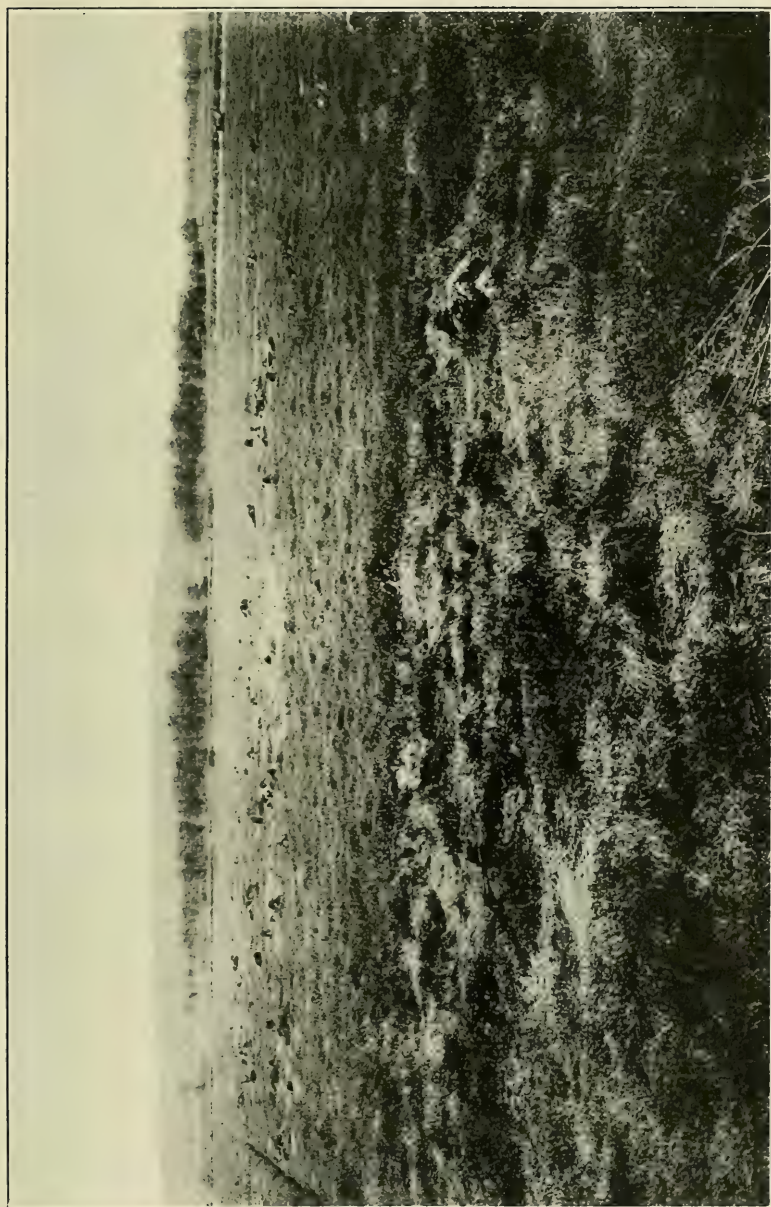
#### EGG STAGE.

In rearing cages the moths laid eggs from various positions, not necessarily resting on the bottom of the cage, but dropping the eggs from whatever position they happened to have assumed. No eggs were found attached to the cranberry vines or sides of the cage, but all were recovered on the cage floor. It is assumed, then, that on the bogs the eggs are laid either when the moths have crawled down to the trash or when they are clinging to vines or grasses. The eggs are so minute that there is little possibility of finding any under natural bog conditions.

The moth has been known to be a prolific egg layer. Felt (6) records one female that laid 700 eggs, 300 of them being deposited on the first day. In the course of observations at Whitesbog, N. J., a female was noted which laid 50 eggs in less than two hours.

The data in Table II give the number of eggs per female secured at Whitesbog, N. J., under insectary conditions.

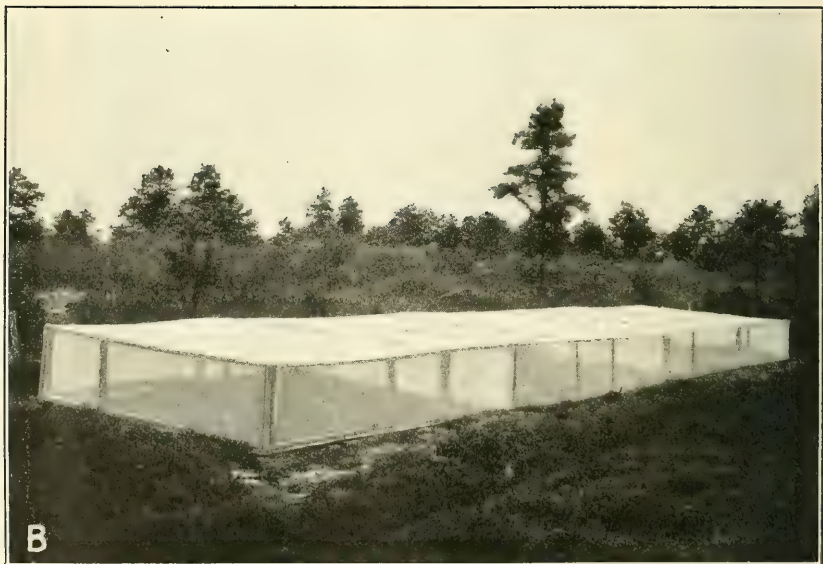
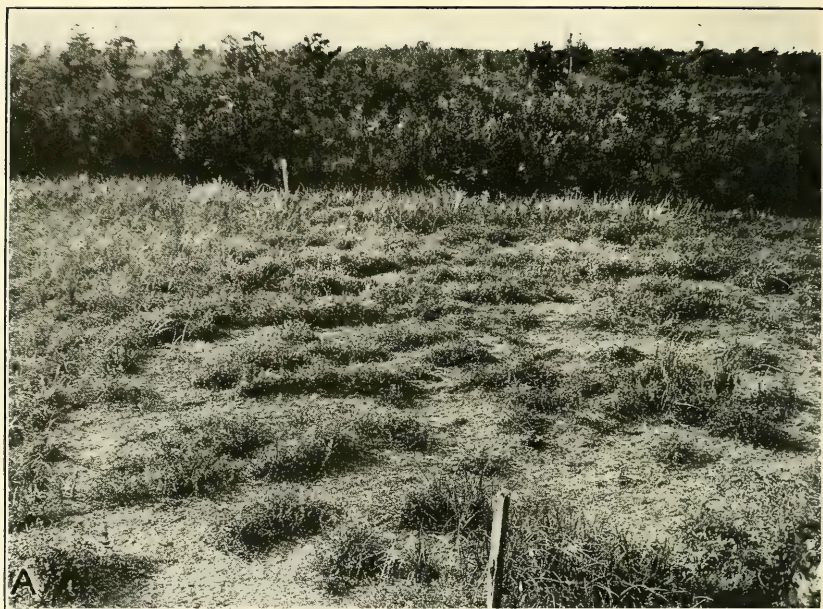
A male and female (reared) were placed in each cage and fed sugar sirup.



WORK OF THE CRANBERRY GIRDLER (*CRAMBUS HORTUELLUS*).

Severely injured cranberry bog, showing large dead area in foreground and smaller dead areas beyond. (Original.)

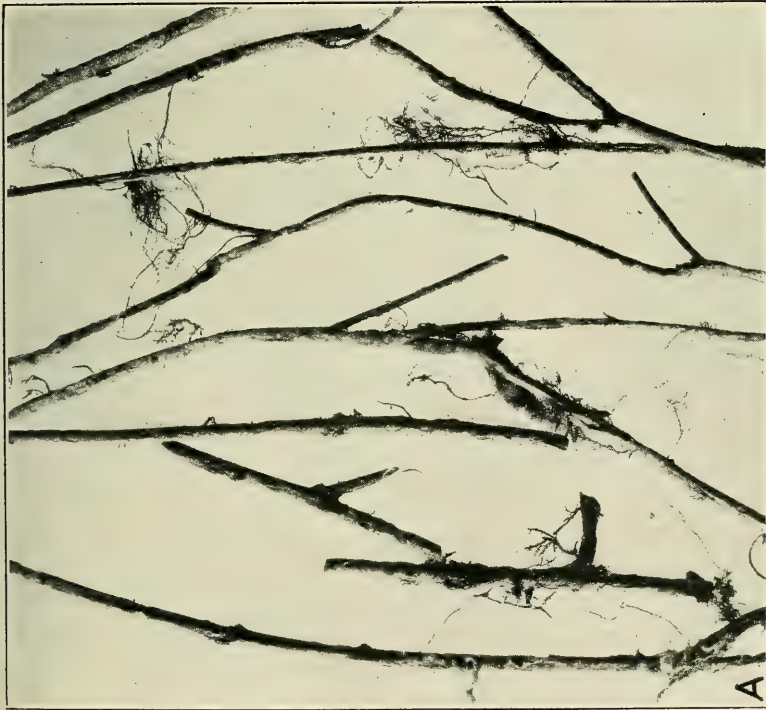




THE CRANBERRY GIRDLER.

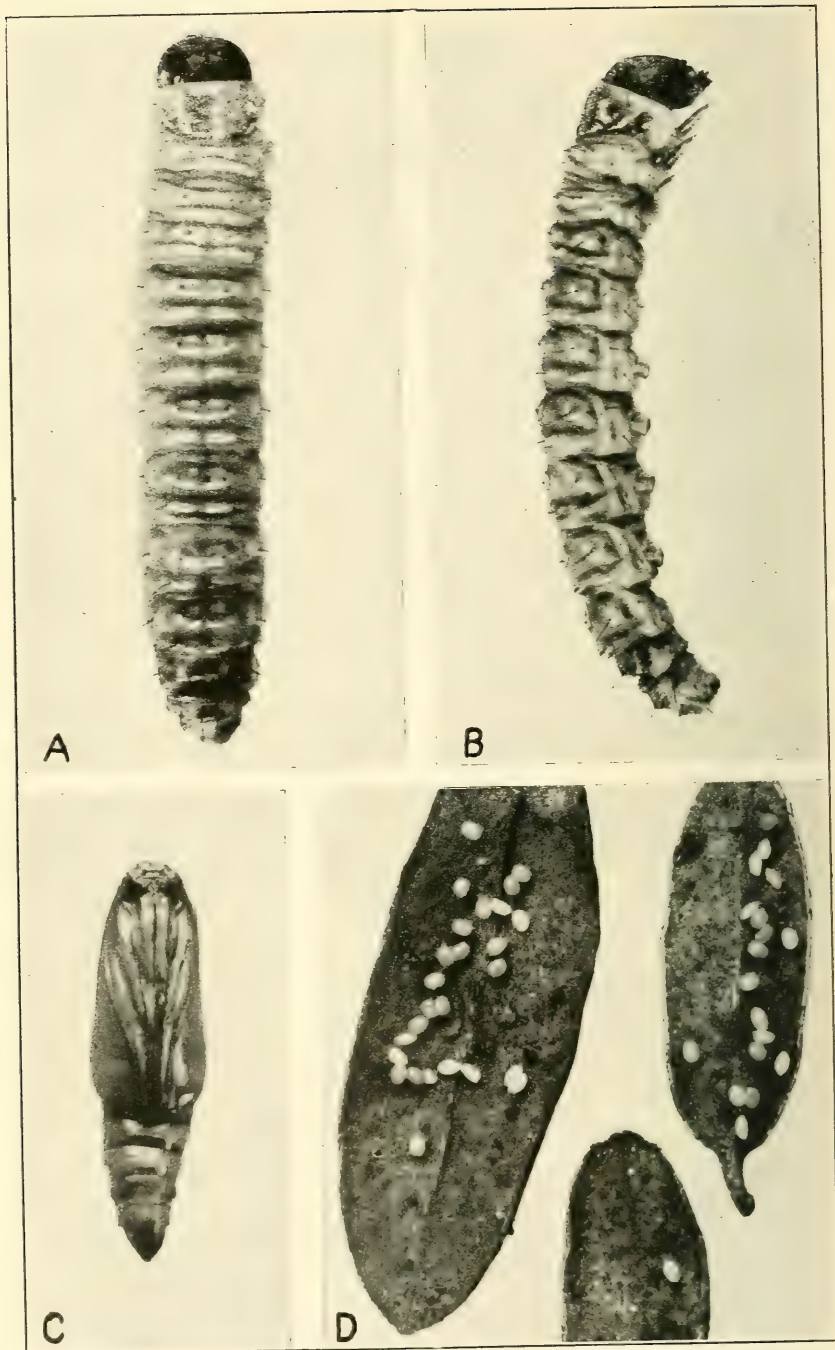
A.—Mild case of injury to cranberry vines. B.—Cage used in sanding experiment at Whitesbog, N. J. (Original.)





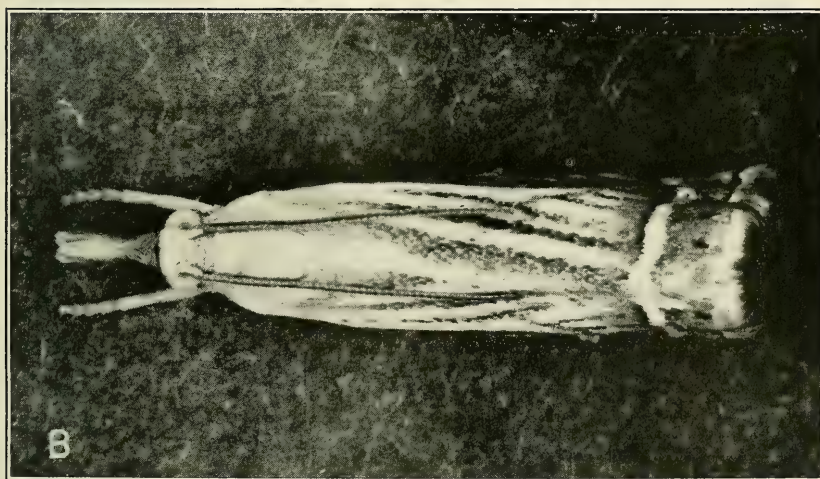
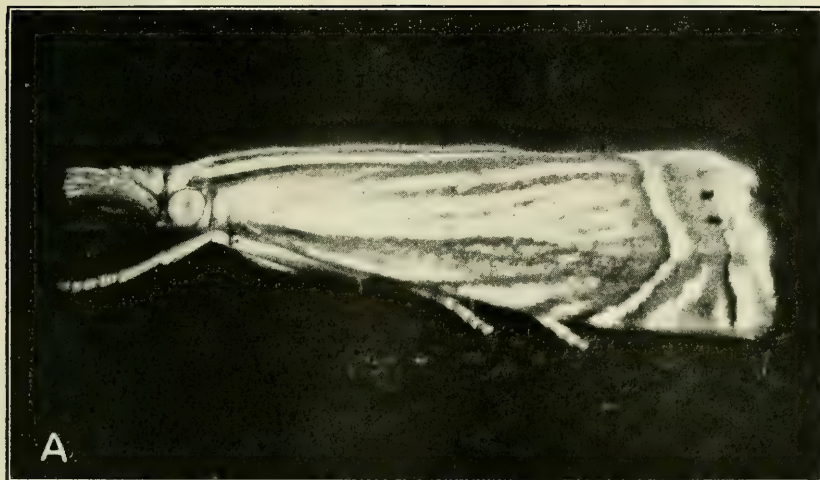
DAMAGE BY THE CRANBERRY GIRDLER.

A.—Cranberry runners gnawed by the larvæ. B.—Larval feeding marks on cranberry vines in rearing cage. (Original.)



STAGES OF THE CRANBERRY GIRDLER.

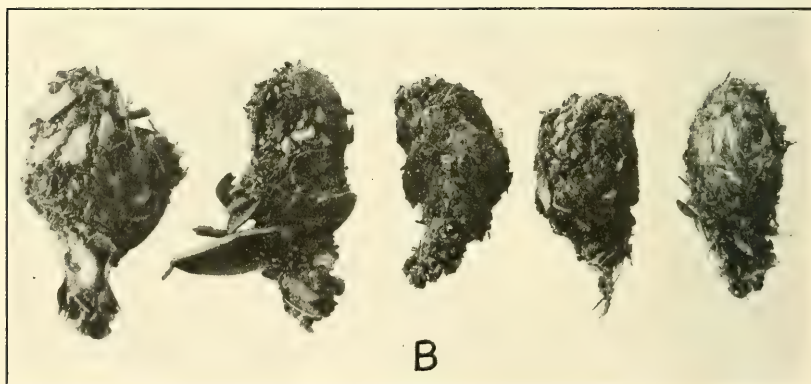
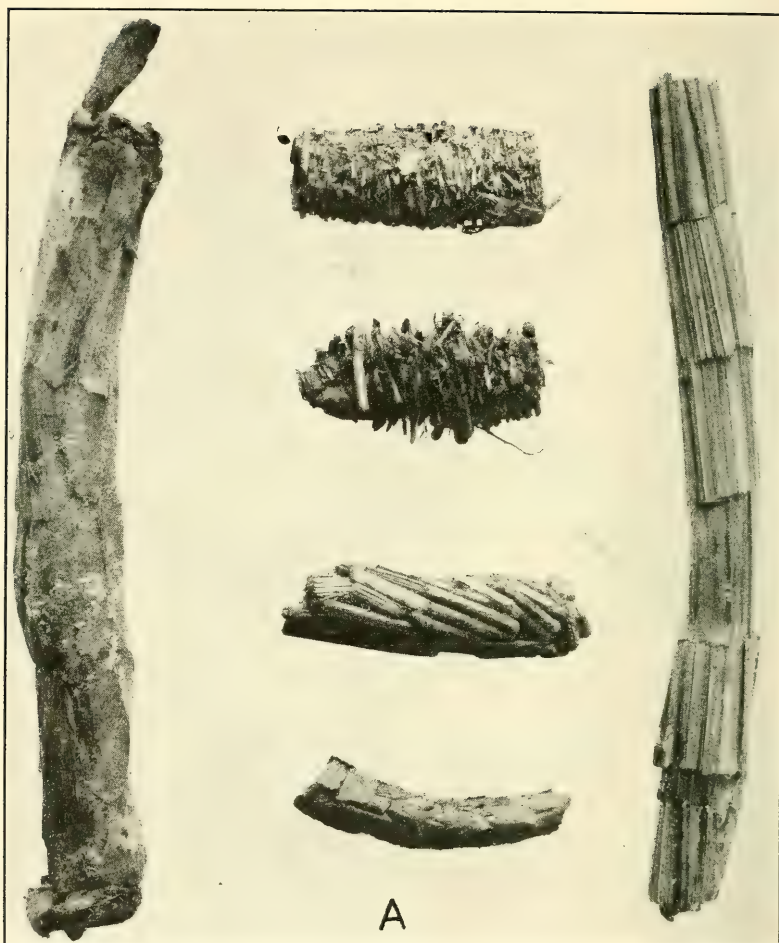
A.—Dorsal view of last-stage larva, enlarged 9 times. B.—Lateral view of last-stage larva, enlarged 9 times. C.—Pupa, enlarged 6 times. D.—Eggs on fallen cranberry leaves. (Original.)



**THE CRANBERRY GIRDLER.**

A.—Adult moth, viewed from side. B.—Adult moth viewed from above. Photographed from life, enlarged 9 times. (Original.)





COCOONS OF CRANBERRY GIRDLER AND CADDICEWORMS.

A.—Caddiceworm cases, sometime mistaken for those of the girdler, twice enlarged. B.—Types of cocoons of cranberry girdler, twice enlarged. (Original.)

TABLE II.—*Number of eggs per female of the cranberry girdler, Whitesbog, N. J., 1915.*

| Pair No. 1.         |                 | Pair No. 2.         |                 | Pair No. 3.         |                 | Pair No. 4.         |                 |
|---------------------|-----------------|---------------------|-----------------|---------------------|-----------------|---------------------|-----------------|
| Date of deposition. | Number of eggs. | Date of deposition. | Number of eggs. | Date of deposition. | Number of eggs. | Date of deposition. | Number of eggs. |
| June 9.....         | 7               | June 1.....         | 1               | May 22.....         | 79              | July 24.....        | 55              |
| June 10.....        | 98              | June 2.....         | 1               | May 23.....         | 103             | July 25.....        | 8               |
| June 11.....        | 30              | June 3.....         | 1               | May 24.....         | 0               | July 26.....        | 78              |
| June 12.....        | 12              | June 4.....         | 6               | May 25 and 26       | 32              | July 27.....        | 21              |
| June 13.....        | 14              | June 5.....         | 17              | May 27.....         | 9               | July 28.....        | 49              |
|                     |                 | June 6.....         | 59              | May 28.....         | 12              | July 29.....        | 3               |
|                     |                 | June 7.....         | 75              |                     |                 | July 30.....        | 17              |
|                     |                 |                     |                 |                     |                 | July 31.....        | 12              |
|                     | 161             |                     | 160             |                     | 235             |                     | 243             |

The greatest number of eggs laid in a single day by one female was 103, and the greatest number laid during the life of a given female was 243. The length of the egg stage varies with the season, those eggs deposited in May requiring a longer incubation period than do those laid in July, as shown in Table III.

TABLE III.—*Length of the egg stage of the cranberry girdler, Pemberton and Whitesbog, N. J., 1915.*

| Date of deposition. | Date of hatching. | Length of stage. | Date of deposition. | Date of hatching. | Length of stage. |
|---------------------|-------------------|------------------|---------------------|-------------------|------------------|
|                     |                   | <i>Days.</i>     |                     |                   | <i>Days.</i>     |
| May 21.....         | June 8.....       | 18               | July 25.....        | Aug. 1.....       | 7                |
| May 22.....         | .....do.....      | 17               | July 26.....        | .....do.....      | 6                |
| May 23.....         | .....do.....      | 16               | .....Do.....        | Aug. 2.....       | 7                |
| .....Do.....        | June 10.....      | 18               | July 27.....        | Aug. 3.....       | 7                |
| May 26.....         | June 11.....      | 16               | July 28.....        | Aug. 5.....       | 8                |
| June 9.....         | June 17.....      | 18               | July 30.....        | Aug. 6.....       | 7                |
| June 10.....        | .....do.....      | 7                | July 31.....        | .....do.....      | 6                |
| June 11.....        | June 19.....      | 8                | Aug. 7.....         | Aug. 13.....      | 6                |
| June 12.....        | .....do.....      | 7                | Aug. 9.....         | Aug. 15.....      | 6                |
| July 24.....        | Aug. 1.....       | 8                |                     |                   |                  |

Average length of the egg stage, 9.63 days.

#### LARVA STAGE.

The larva leaves the egg through a hole which it cuts in the apex, or slightly to one side of the apex, and emerges as soon as the aperture is large enough to permit the passage of the head, crawling rapidly out and appearing very active at this period. In small cans the larvæ were fed fine cranberry roots, the bark and wood feeding habit being acquired apparently during later life. As remarked by Ainslie (12), some species of Crambinae defy all attempts to rear the larvæ, and *C. hortuellus* falls into this class in the experience of the writer.

Investigations conducted in this region demonstrated beyond doubt that there is only one generation annually. Field records kept on a number of badly infested bogs throughout the entire season showed only a single flight of moths from about June 10 to mid-July, after which there was no further evidence of moths until the following year. This was also demonstrated in a mosquito-bar cage covering 2.4 square rods, from which moths issued from June 10 to July 8, and although oviposition occurred in the cage, none of the larvæ pupated during that season.

Larvæ are rarely found in wet situations or in places where a lack of drainage is materially affecting the productiveness and health of the vines.

The drier locations, such as knolls, the high margins of the bogs, and well-drained areas having a considerable quantity of fallen leaves and trash under the vines are the places injuriously infested. The character of the soil is not so important a limiting factor as the drainage. Severe injury occurs on mud and peat bottoms as well as on savannas, provided a good layer of trash is present and the land is well drained.

Larvæ are never found feeding in exposed positions, but always buried beneath more or less trash. When exposed to the light, as when trash is turned over, they usually are found in a curved position and motionless. After a period of about 10 seconds the larvæ will start crawling rapidly for cover, and it is at this time that they are most easily detected. The trashy nature of the infested situations also renders their location difficult. Many growers have failed utterly to locate the larvæ, although the vines may have shown injury of an extreme type.

The amount of damage done by the cranberry girdler seems out of all proportion to the number of larvæ to be found in a given location. In one instance, however, the writer found 30 cocoons containing larvæ and 1 naked larva in an area of about 4 square feet.

What appears to be the most important point in the seasonal history of this pest from the standpoint of its control is the period when cocoon making begins. The few publications available on the seasonal history of the cranberry girdler present various statements regarding the time of cocooning. Some writers have placed the period as late as November, and others have indicated this period as beginning at varying dates in September and October. Realizing the importance of knowing more definitely when cocooning commenced, the writer has made collections of larvæ and cocoons in the fall, and from these data it may be stated for New Jersey conditions that some larvæ form cocoons in late September and the majority in early October. Records obtained from bogs in different localities are shown in Table IV.



TABLE IV.—*Cocooning records of the cranberry girdler in New Jersey, 1915.*

| Date.         | Number of larvæ in cocoons. | Number of naked larvæ. | Date.        | Number of larvæ in cocoons. | Number of naked larvæ. |
|---------------|-----------------------------|------------------------|--------------|-----------------------------|------------------------|
| Sept. 8.....  | 0                           | 21                     | Oct. 5.....  | 9                           | 1                      |
| Sept. 14..... | 0                           | 15                     | Oct. 11..... | 6                           | 1                      |
| Sept. 19..... | 0                           | 7                      | Oct. 15..... | 37                          | 1                      |
| Oct. 1.....   | 3                           | 17                     | Oct. 19..... | 1                           | 0                      |
| Oct. 4.....   | 0                           | 2                      | Nov. 17..... | 26                          | 0                      |

The foregoing figures, obtained under actual bog conditions, show that cocoons were first found October 1, although search was not made for them between September 19 and that date. Naked larvæ were abundant on October 1, but this condition soon changed, and by the 5th of October larvæ in cocoons outnumbered the naked ones.

After making the cocoon, the larva lies dormant within until spring of the following year, at which time pupation occurs. Larvæ in cocoons are able successfully to withstand the usual winter flowage, which is applied, as a rule, in December and held until the following April or May. Some few are able to withstand a flowage lasting until July, although an infestation is always greatly reduced by such late holding.

The cocoon is not impervious to water and, in fact, becomes filled with water about three days after submergence. After 24 hours' submergence in a solution tinged with red, the inner wall of the cocoon was found entirely reddened, with no free water around the larvæ. Similar results were obtained with another cocoon after 48 hours' submergence, while at the end of four days three cocoons were entirely filled with the solution.

#### PUPA STAGE.

Pupation occurs after the removal of the winter flowage and is dependent upon the time of this removal. On dry bogs it may occur in late April or May, and on winter-flowed bogs it may be retarded by late holding of the flowage until July. No evidence has been noted of pupation taking place while the winter flowage was on; in fact, the examination of cocoons within a day or two after the drawing of the winter flowage showed all such to contain larvæ.

After pupation has occurred the bog may be reflowed for several days without effecting the death of the pupa. On one occasion a pupa in its cocoon was found alive on the bog after submergence for between five and six days.

Pupal records have been difficult to obtain, because the opening of the cocoon for purposes of observation is disturbing to the larva and is likely to result either in its death or in delaying its transformation to the pupa. The records at hand show that the stage lasts,

on the average, 21 days. (See Table V.) Under natural bog conditions, following the drawing of the winter flowage about May 10, it is very likely that the pupal period is several days shorter in duration than as stated. The pupa is always found with the head pointing toward the neck of the cocoon, eventually permitting the easy emergence of the moth.

TABLE V.—Length of pupa stage of the cranberry girdler, Pemberton, N. J., 1914.

| Experiment No. | Date of pupation.    | Date adult emerged. | Length of stage. | Experiment No. | Date of pupation. | Date adult emerged. | Length of stage. |
|----------------|----------------------|---------------------|------------------|----------------|-------------------|---------------------|------------------|
|                |                      |                     | Days.            |                |                   |                     | Days.            |
| 1.....         | Apr. 28 <sup>1</sup> | ( <sup>2</sup> )    | .....            | 9.....         | Apr. 30           | ( <sup>2</sup> )    | .....            |
| 2.....         | Apr. 29 <sup>1</sup> | May 11              | 12               | 10.....        | May 2             | ( <sup>2</sup> )    | .....            |
| 3.....         | ..do..               | May 15              | 16               | 11.....        | ..do..            | May 18              | 16               |
| 4.....         | ..do..               | May 18              | 19               | 12.....        | ..do..            | ..do..              | 16               |
| 5.....         | ..do..               | May 20              | 21               | 13.....        | May 7             | June 5              | 29               |
| 6.....         | ..do..               | May 27              | 28               | 14.....        | May 23            | June 13             | 21               |
| 7.....         | ..do..               | May 29              | 30               | 15.....        | May 29            | June 17             | 19               |
| 8.....         | Apr. 30              | ..do..              | 29               | 16.....        | ..do..            | ..do..              | 19               |

Average days, 21.15.

<sup>1</sup> Approximate.

<sup>2</sup> Died.

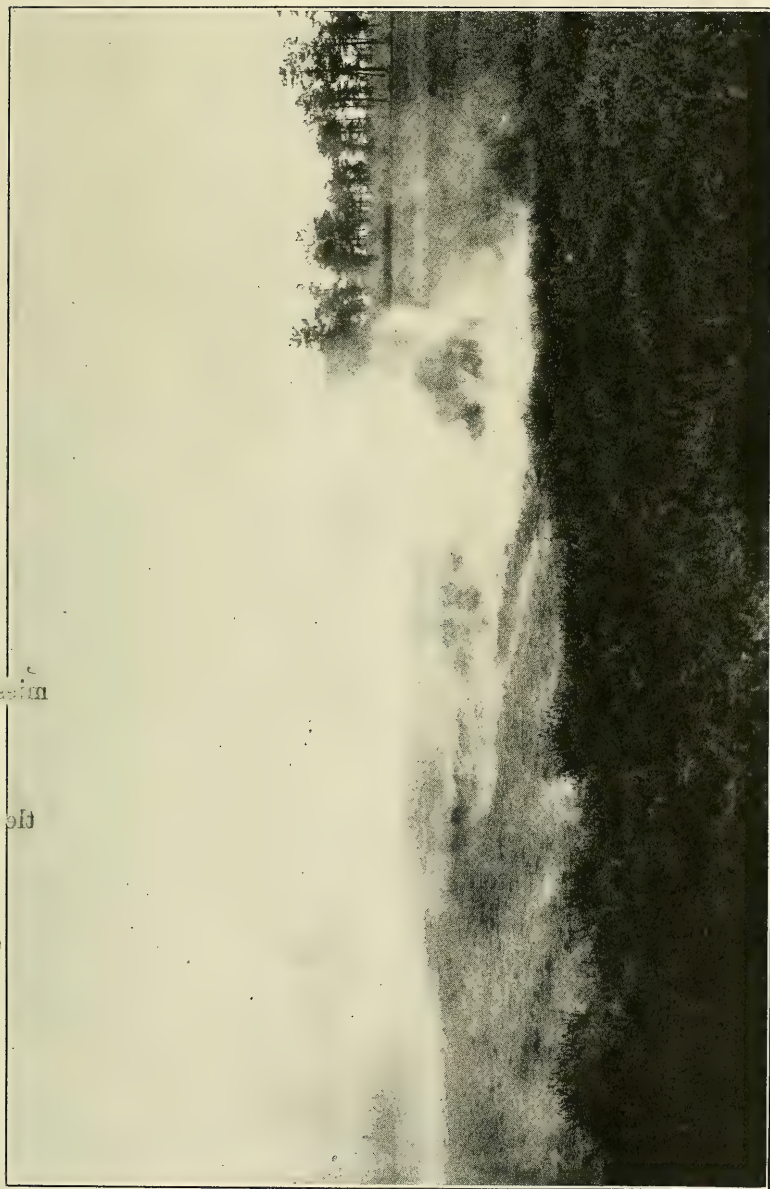
### NATURAL ENEMIES.

Among the parasites there appear to be very few which attack the cranberry girdler. No parasites were obtained in the rearing cages, but occasionally when opening cocoons the remnants of a parasite in one stage or another were found. From such findings two species of Ichneumonidæ were secured. The habit of concealed feeding of the girdler larvæ must be a great protection against parasitic ene , and the winter flowing of the bogs probably also tends to lessen the activities of parasites.

In areas of severe girdler infestation spiders have been found to be very abundant as well as have various species of ground bee s. Among the ground beetles *Harpalus caliginosus* Fab. and *Anisodactylus harrisii* Lec. have been collected.

Very often an area of vines infested with girdler larvæ will be invaded by field mice, and the burrows just beneath the surface will run throughout the entire section. While mice occasionally cut off cranberry vines which are in the line of a runway, they should be classed as minor pests of the cranberry industry. The work of mice may be recognized by the diagonal cut of the severed vine and the furrows made across the end by their teeth. It is thought, however, that the mice search for girdler larvæ and are instrumental in reducing large infestations. They nest in roundish houses built of grasses above the level of winter flowage.

Among the birds which prey on insects the swallows are perhaps the most useful in capturing girdler moths. At Howardville, N. J., a swallow followed the writer the length of one of the bogs, and as



**A SEVERE REMEDIAL MEASURE AGAINST THE CRANBERRY GIRDLER.**

Burning a cranberry bog, a practice occasionally resorted to in very severe outbreaks. (Original.)





the moths, frightened from the vines, rose into the air the swallow darted for them and captured many.

At present, natural enemies do not appear to be potent factors in the control of the girdler on cranberry bogs.

### REMEDIAL MEASURES.

Under the heading of remedies fall such methods of treatment as spraying, the use of repellents, burning, trap lights, flooding, and sanding. Of these measures, flooding and sanding have given the best satisfaction, as indicated by the work conducted in New Jersey.

#### SPRAYING.

Owing to the habit of the larvæ of feeding on roots and runners under cover of the trash beneath the vines, there seems to be no hope of developing a method of combating them in which reliance can be placed on spraying. In addition to the trash which hides the larvæ, the dense mat of vines covering the bog prevents a large portion of the spray material from reaching even the trash.

#### REPELLENTS.

It has been suggested occasionally by growers that commercial fertilizers might act as repellents of the girdlers and at the same time stimulate the vine growth. The opportunity to study this method of treatment was afforded at Whitesbog, N. J., where fertilizer experiments on cranberry bogs have been carried on by the New Jersey experiment station for a period of four years. No fertilizer was applied to the plats the fourth year, owing to the excessive vine growth produced during the previous three years. Muriate of potash has been held by some to afford protection from certain insects owing to its repellent action, and four of the plats to which this material was applied, along with other ingredients, were kept under observation by the writer. The data in Table VI<sup>1</sup> show the fertilizers and the amounts applied on four plats, consisting of one-twentieth of an acre each.

TABLE VI.—*Experiment with fertilizers as repellents against the cranberry girdler, Whitesbog, N. J., 1915.*

| Plat No. | Fertilizer tested.                                                                  | Plat No. | Fertilizer tested.                                                                  |
|----------|-------------------------------------------------------------------------------------|----------|-------------------------------------------------------------------------------------|
| 11.....  | 10 pounds muriate of potash, 25 pounds acid phosphate, 10 pounds ammonium sulphate. | 29.....  | 10 pounds muriate of potash, 15 pounds phosphate rock, 10 pounds ammonium sulphate. |
| 13.....  | 10 pounds muriate of potash, 25 pounds acid phosphate, 20 pounds dried blood.       | 31.....  | 10 pounds muriate of potash, 15 pounds steamed bone, 10 pounds ammonium sulphate.   |

<sup>1</sup> Extracted from Proceedings of the 46th Annual Meeting of the American Cranberry Growers' Association.

The fertilizers listed in Table VI have been of no avail in repelling the girdlers; in fact, these plats in 1916 showed serious injury, as evidenced by the considerable areas of girdled vines found on them. In general, it may be said that the use of fertilizers tends to make conditions more favorable for girdler infestation by increasing the amount of vine and foliage production and thus in direct proportion increasing the trash on the ground beneath the vines. This, however, should not deter anyone from using fertilizers on cranberry bogs where the vines need stimulation, but should be taken as a caution that girdler infestation is likely to follow a heavy production of vines, particularly on well-drained land.

In a test to determine the repellent value of certain materials a lumpy and granular residue, said to be a by-product of a gasworks, was applied to an infested piece of land by broadcasting at the rate of 650 pounds per acre. The larvæ were not repelled and were as abundant at the time of cocooning on the treated plat as on the adjacent untreated plats.

#### BURNING.

Burning infested areas has been recommended in the past and occasionally has been resorted to by growers. When a bog is burned over (Pl. VII), a large quantity of the trash remains unconsumed on the bog floor, but it is probable that the heat generated is great enough to kill the larvæ, naked or in cocoons, that may have been buried in this débris. Other methods of controlling the girdler have been devised which do not entail destruction of the vines by burning, and the practice therefore is not recommended.

#### TRAP LIGHTS.

Capturing the moths by trapping with lights was tried for two seasons with very unsatisfactory results. On one occasion four moths were captured at a stationary light in the course of a night. The tests with lights were made in the height of the flying season, and the results showed conclusively that the moths are not attracted to lights in sufficient numbers to warrant employing this method of capture.

#### LATE HOLDING OF THE WINTER FLOWAGE.

By late holding of the winter flowage is meant maintaining the winter head of water over the vines from the time it is applied in December or thereabouts until some time between July 1 and August 1. Holding the flowage until July 1 does not always satisfactorily destroy girdler infestations, but if the head is maintained until July 15 much better results are obtained. Occasionally a grower is met who has kept the water on the bog until August 1. and, while



this treatment is very satisfactory from the standpoint of destroying the girdlers, it may result in a very poor bud formation and a light crop of berries the following year. Some of those who have tried holding the flowage until mid-July have reported that the crop the year following yielded an increase of 100 per cent over a normal one, showing that this treatment may be used without monetary loss, provided frosts, which may destroy part of the prospective double crop, are not encountered in the cropping year.

Holding the flowage until July 14 or later results in the loss of the current year's crop, but this procedure is good practice where the girdler infestation is severe and perhaps complicated by an infestation of the blackhead fireworm (*Rhopobota vacciniana* Pack.). Considerable expense is saved the grower by allowing the bog to go one year without a crop, and the treatment always results in producing a cleaner bog, especially if the one so handled has been invested by grass and weeds.

June 18 is the latest date, in the knowledge of the writer, to which the winter flood can be held and a good crop secured the same season. This was accomplished on a deep-flowed bog of Early Black vines near Pemberton, N. J.

In the event of holding the winter flowage until July 15, or a little later, successful control of the girdler will be secured, but not extermination. A few of the insects will escape even this treatment, and at the end of three or four years the infestation again may be severe. The mistake made by many growers is in permitting the injury to assume large proportions before attempting control. The first signs of girdler injury should be noted and the remedy applied before the pest gains headway and large areas of vines are destroyed. The presence of large numbers of the moths on a bog in June and July should serve as a warning that the vines are in a fair way of being severely damaged.

#### FALL FLOODING.

Fall flooding affords the most satisfactory control of the girdler, and will result in practical extermination of the pest until reinfestation comes from the upland or other bogs, if it is applied at the proper time. As shown in the study of the seasonal history, the larvæ make cocoons in the fall, and if the fall flowage is applied after the cocoon is formed, the larva within will not be injured, even though this flowage lasts two weeks or more. However, if the flowage is applied before cocoon making begins, the naked larvæ will be killed certainly in a week, and it is probable that five days is ample time for submergence, although some growers prefer to hold the flowage two weeks to insure a thorough treatment.

For New Jersey, cocoon making begins in a large way the first week in October, and it is therefore essential to reflow the bog dur-

ing the latter part of September. If the bog is vined with a variety of early berries it will not be difficult to have them picked early so that flooding can be done at the proper time. With late berries, such as Howes, this treatment is not in vogue and some other remedy must be attempted. It is of course essential to have sufficient water in storage to accomplish the fall flooding, and a lack of storage water at this season of the year is the stumbling block which limits the practice of fall flooding to a very few of the New Jersey bogs.

If the fall flowage is applied later than the first week in October most of the worms will not be killed, as is shown in the following notes made on a bog at Mays Landing, N. J.: On October 15 the bog was examined and was found to have been severely damaged. A search for larvæ and cocoons was made, and 30 larvæ in cocoons and one naked larva were secured. The flowage was put on October 22 and held until November 8, a period of 17 days. On November 17 another examination was made, and 26 live larvæ and 1 dead larva in cocoons were collected. This treatment was therefore entirely unsatisfactory.

At Pemberton, N. J., a newly infested bog was flooded from September 19 to October 3, a period of 14 days, with the result that the following season no further dying of the vines occurred and no flight of moths was observed. This indicated very successful control.

Fall flooding immediately after picking the crop, whether this be early or late, is a treatment to be commended, even though girdlers are not present, since it helps in the control of the yellow-headed fireworm (*Peronea minuta* Rob.), the red-striped fireworm (*Gelechia trialbamaculella* Cham.), the toad bug (*Phylloscelis atra* Germ.), the blossom worm (*Epiglaea apiata* Grote), and other insects of minor importance.

#### SPRING FLOODING.

Wherever opportunity offered, examinations were made of bogs after the reflowage had been removed in the spring, to determine if flooding during the pupa stage for various lengths of time had killed the pupæ. In the season of 1915 a bog from which the winter flowage had been drawn on May 10 was reflowed June 9, and a certain area, known to be infested, was watched to ascertain the number of hours it was covered by the flowage. This period proved to be 24 hours, and soon afterward two cocoons, each of which contained a live pupa, were found upon the bog. Moths issued from these pupæ on June 15 and June 19. From another area on the same bog, which had been submerged about 30 hours, 11 cocoons were collected, and these yielded 10 pupæ. Moths issued from these pupæ as follows: June 14, three; June 15, two; June 16, one; June 17, three.

During the season of 1916 a bog was observed which had the following history: The winter flowage was drawn off on April 9. The first reflow lasted  $5\frac{1}{2}$  days on the girdler-infested area, or from May 12 to May 18. The second reflow was held 36 hours, dating from May 31, and the third reflow was removed at the end of 18 hours, on June 9. On June 12, three days later, girdler moths were found flying over the infested area, and since no other infestation existed near by, this was ample evidence that the three reflowings had not destroyed the immature stages.

On one occasion a live pupa was collected in its cocoon where the reflow had lasted  $5\frac{1}{2}$  days. The winter flowage had been drawn May 10, and the reflowing occurred from June 9 to June 15. Two weeks later girdler moths were very abundant on this area. These records indicate that spring reflows occurring during or near the pupa period and when held for periods lasting as long as  $5\frac{1}{2}$  days do not give control of the girdler.

#### SANDING.

There has been considerable hostility to the practice of sanding cranberry bogs by some of the New Jersey growers, due largely, it seems, to the fear of increasing the fungous troubles of this fruit. On the other hand, there are a few growers who, while not consistent "sanders," are greatly in favor of the practice although little, if any, experimental work has been performed in New Jersey to determine whether or not the losses due to fungous diseases have increased on sanded areas. It has long been customary in Massachusetts to sand the bogs, and such treatment has a well-recognized value in the control of certain cranberry insects, notably the cranberry tipworm (*Dasyneura vacciniæ* Smith) and the cranberry girdler.

Sand should be spread on the bog in the fall, winter, or early spring, preferably in late fall so as to have it become well settled around the vines by the winter flowage. Occasionally, during cold weather, sand may be spread on the ice, resulting, when thawing ensues, in an even covering of the ground. For girdler infestations a layer of sand not less than 1 inch in thickness is required, and it will be found far better on most New Jersey bogs that have not been sanded previously to apply a coat nearer 2 inches in thickness. The sand is of value in several ways: First, if the coat is sufficiently thick it prevents the emergence of the moths; and, second, it covers the trash on the bog floor, producing clean conditions unfavorable for girdler infestation. In locations where girdler injury has already occurred it covers the injured vines, causing them to throw out new roots, and invigorating them to such an extent that recovery is rapid.



For those who undertake the sanding method of controlling girdlers it should be borne in mind that there is some risk, attendant upon this practice, of increasing the fungous troubles of the fruit, and one should be prepared to spray sanded bogs with a fungicide such as Bordeaux mixture.

Experimental work is not altogether conclusive as to the thickness of the coat of sand which will prevent emergence of the moths from cocoons. Franklin (11, p. 19) found that an even covering of sand 1 inch in thickness effectually prevented moth emergence in small cages, while the writer's data, obtained in a mosquito-bar cage placed on a cranberry bog, lead him to conclude that an even coat, 1 inch in thickness, will not be obtained by the grower in the actual practice of sanding and that considerable numbers of moths will emerge through the sand.

The sanding experiment performed at Whitesbog, N. J., was essentially as follows: Three plats were laid off where the vines showed severe injury and where, in fact, they had been killed over a considerable extent. Two of the plats were sanded fairly evenly on November 23, 1914, the depth varying from an inch to an inch and a half. The winter flowage was put on in December and removed May 8, 1915. The same day three cocoons were removed from beneath the sand in plat 2, and on May 10 two cocoons were dug out, all of which contained live larvæ. A tight mosquito-bar cage (Pl. II, B) was built over the three plats a few days later, and emergence of moths was first noted June 10, 1915.

TABLE VII.—*Emergence of moths of the cranberry girdler in sanding experiment at Whitesbog, N. J., 1915.*

| Date.        | Number of moths emerged.                        |                                                |                                                 |
|--------------|-------------------------------------------------|------------------------------------------------|-------------------------------------------------|
|              | Plat 1,<br>area, 173<br>square feet,<br>sanded. | Plat 2,<br>area, 248<br>square feet,<br>check. | Plat 3,<br>area, 222<br>square feet,<br>sanded. |
| June 10..... | 4                                               | 12                                             | 0                                               |
| June 11..... | 7                                               | 41                                             | 0                                               |
| June 12..... | 10                                              | 34                                             | 1                                               |
| June 15..... | 41                                              | 64                                             | 12                                              |
| June 13..... | 18                                              | 3                                              | 3                                               |
| June 18..... | 21                                              | 8                                              | 9                                               |
| June 23..... | 4                                               | 1                                              | 5                                               |
| July 2.....  | 0                                               | 0                                              | 1                                               |
| July 8.....  | 1                                               | 0                                              | 0                                               |
| Total.....   | 106                                             | 160                                            | 31                                              |

Owing to the distance of the cage from the field laboratory it was not practicable to remove and count the moths each day. The data show that the greatest number of moths emerged from the unsanded plat, which was also the largest plat, but that 1.55 moths

emerged per square foot in the unsanded plat as compared with 1.61 moths in plat 1, sanded. Plat 3 was known to have a lighter infestation than the others when the experiment was started.

There were one or two places, particularly around a stump, on the sanded areas where the sand had washed a little thin during the period of winter flowage, but these spots were insignificant in size, and the data presented lead to the conclusion that a 1-inch coat of sand applied under natural bog conditions with a great deal more care than would be given by the average grower is not effectual in preventing the emergence of girdler moths from their cocoons.

#### RECOMMENDATIONS FOR CONTROL.

The most effective control measure that the writer has seen applied for this insect is the fall flooding immediately after picking the crop, when this operation can be completed in time to apply the water before the last of September. This treatment is effective, because it comes before the worms have spun their cocoons, and a reflow lasting not more than a week is undoubtedly of sufficient duration to kill all naked girdler larvæ.

If the berries can not be removed from the vines in time to permit fall flooding before the last of September, or if the water supply is insufficient, the next best method of control is to hold the winter flowage over the vines until July 20, thereby losing one crop of berries, but gaining a clean bog and the possibility of having a crop twice the normal in quantity the following year.

In the event that the foregoing remedies can not be employed, recourse may be had to sanding and better cultural methods. It is doubtful if a coat of sand less than  $1\frac{1}{2}$  inches in thickness can be relied upon to prevent emergence of the girdler moths and, while this is an expensive operation, there are many New Jersey bogs, particularly those having peat or mud bottoms, which would be benefited greatly by a thorough sanding. A 1-inch coat of sand will be found of value for invigorating injured vines and in so far as it covers the trash on the bog floor will render conditions less favorable for further infestation by the girdlers. If the fruit produced on sanded lands is less sound than it was prior to sanding, this condition may be corrected to a large extent by spraying with Bordeaux mixture in the proper season.

Pruning, along with sanding, should be practiced, and these measures, together with the removal of obnoxious weeds and grasses, constitute better cultural methods, all of which aid very materially in making cranberry vines healthier and freer from damaging insects.

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# UNITED STATES DEPARTMENT OF AGRICULTURE



## BULLETIN No. 555



Contribution from the Office of Public Roads and Rural  
Engineering, LOGAN WALLER PAGE, Director

Washington, D. C.



November 26, 1917

### STANDARD FORMS FOR SPECIFICATIONS, TESTS, REPORTS, AND METHODS OF SAMPLING FOR ROAD MATERIALS.

As Recommended by the First Conference of State Highway Testing Engineers and Chemists, Washington, D. C., Feb. 12-17, 1917.

#### CONTENTS.

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#### INTRODUCTION.

With the joint participation of the Federal Government and States in the construction of highways under the Federal aid road act of July 11, 1916, it became necessary for the United States Office of Public Roads and Rural Engineering to familiarize itself thoroughly with the practice of different States in highway work in order to facilitate perfect cooperation. The construction of highways may be considered under two main headings: (1) Materials used and (2) methods used. The report of this conference has to do with the first subject.

As a result of a canvass of the various States made by circular letter in the latter part of 1916, it was ascertained that less than one-half of the States had proper facilities for testing materials used by them in highway work, and many had no facilities at all. At that time a large majority of the States indicated their willingness to cooperate with the Office of Public Roads and Rural Engineering and, if possible, to send representatives to attend a conference upon the subject of materials used in highway work. After the conference had been called it was found that many of the States which had signified their willingness to cooperate could not send representatives at the time appointed. However, a widespread interest in the

work of the conference was expressed, and numerous requests were received for copies of the report of the conference. Under existing conditions and the general difficulty of securing representatives from all parts of the country to meet at a given point, it is considered highly gratifying that 26 representatives from 21 States attended.

Because it was felt that a sufficient number of permanent organizations having to do with highway matters now exist, no additional permanent organization was contemplated, but the Office of Public Roads and Rural Engineering proposes to call other conferences from time to time as they may be needed. It is not intended to conflict or compete in any way with the permanent organizations, and, in fact, it is suggested that the conferences adopt the standards of such organizations whenever they are considered reasonably satisfactory.

The purposes of the conference announced in advance were as follows:

- (1) To encourage the establishment of well-equipped State highway laboratories.

- (2) To recommend for general adoption standard forms of specifications for various types of road materials as applied to specific uses.

- (3) To recommend for general adoption a comprehensive set of standard tests for various types of road materials.

- (4) To recommend for general adoption uniform methods of reporting test results of various types of road materials.

- (5) To recommend for general adoption standard methods of sampling and inspecting various types of road materials.

- (6) To outline a plan of cooperative research on the part of the States in connection with the value of physical and chemical tests of various types of road materials as related to their use.

- (7) To recommend methods whereby the maximum efficiency of the laboratory may be developed as well as its maximum usefulness to highway engineers.

It was realized that lack of time would prevent the first conference from considering all materials of interest in highway engineering. Therefore its attention was confined to recommendations relating to specifications, testing, sampling, and reporting tests on those materials which are included in this report. It is hoped to cover other materials at later conferences.

In the following report the recommendations of the conference are presented in four sections:

- (1) Standard forms of specifications for materials.

- (2) Standard methods of testing materials.

- (3) Standard forms of reporting test results.

- (4) Standard methods of sampling materials.

In the standard forms of specifications such tests as are considered necessary have been included, but, as a rule, specific test limits have not been recommended, owing to recognition of the fact that no one set of test limits could cover satisfactorily the wide differences in methods of construction, available materials, and local conditions peculiar to the various parts of the country. It is expected that engineers who adopt the recommended forms of specifications will insert such test limits as they consider advisable for any given work.

Under standard methods of testing references only are given for description of tests which are published in readily available form. This is also true of the methods of sampling.

LOGAN WALLER PAGE,  
*Director Office of Public Roads and Rural Engineering.*





# RECOMMENDED STANDARD FORMS OF SPECIFICATIONS FOR MATERIALS.

## SPECIFICATION FOR BROKEN STONE FOR WATERBOUND MACADAM.

The broken stone shall consist of angular fragments of (insert types allowable), of uniform quality throughout, free from thin or elongated pieces, soft or disintegrated stone, dirt, or other objectionable matter.

General.

The stone shall meet the following requirements:

Physical properties.

Per cent of wear ----- to -----

(or French coefficient ----- to -----)

\*Toughness ----- to -----

\*Hardness ----- to -----

\*Absorption ----- not more than ----- %

Screenings or No. -- stone.

That portion of the product of the crusher, including the dust of fracture, which, when tested by means of laboratory screens, will meet the following requirements:

Per cent.

Passing -----inch screen ----- 100

Total passing -----inch screen ----- to -----

Top course or No. -- stone.

That portion of the product of the crusher which, when tested by means of laboratory screens, will meet the following requirements:

Per cent.

Passing -----inch screen ----- 100

Total passing -----inch screen ----- to -----

Retained on -----inch screen ----- 100

Bottom course or No. -- stone.

That portion of the product of the crusher which, when tested by means of laboratory screens, will meet the following requirements:

Per cent.

Passing -----inch screen ----- 100

Total passing -----inch screen ----- to -----

Retained on -----inch screen ----- 100

Method of sampling.

Stone shall be sampled for quality and size in accordance with the method described on page -----, paragraphs -----, of these specifications.

Methods of testing.

Tests of the physical properties and sizes of the stone shall be made in accordance with the methods described or referred to on pages ----- of these specifications, tests Nos. -----.

## SPECIFICATION FOR BROKEN STONE FOR BITUMINOUS MACADAM.

General.

The broken stone shall consist of angular fragments of (insert types allowable), of uniform quality throughout, free from thin or elongated pieces, soft or disintegrated stone, dirt, or other objectionable matter occurring either free or as a coating on the stone.

\* Tests recommended by the conference which it may be desirable to omit in some instances.

**Physical properties.**

The stone shall meet the following requirements:

Per cent of wear-----not more than -----  
 (or French coefficient-----not less than -----.)  
 \*Toughness-----not less than -----  
 \*Hardness-----not less than -----  
 \*Absorption-----not more than -----%

That portion of the product of the crusher which, when tested

**Chips or No. -- stone.**

by means of laboratory screens, will meet the following requirements:

Per cent.  
 Passing ----- inch screen----- 100  
 Total passing ----- inch screen----- to -----  
 Retained on ----- inch screen----- 100

That portion of the product of the crusher which, when tested

**Top course or No. -- stone.**

by means of laboratory screens, will meet the following requirements:

Per cent.  
 Passing ----- inch screen----- 100  
 Total passing ----- inch screen----- to -----  
 Retained on ----- inch screen----- 100

That portion of the product of the crusher which, when tested

**Bottom course or No. -- stone.**

by means of laboratory screens, will meet the following requirements:

Per cent.  
 Passing ----- inch screen----- 100  
 Total passing ----- inch screen----- to -----  
 Retained on ----- inch screen----- 100

Stone shall be sampled for quality and size in accordance with the method described on page -----, paragraphs -----, of these specifications.

**Method of sampling.**

Tests of the physical properties and sizes of the stone shall be made in accordance with the methods described or referred to on pages ----- of these specifications, tests Nos. -----

**Methods of testing.**

### SPECIFICATION FOR BROKEN STONE AGGREGATE FOR LARGE AGGREGATE BITUMINOUS CONCRETE.

**General.**

The broken stone aggregate shall consist of angular fragments of (insert types allowable), of uniform quality throughout, free from thin or elongated pieces, soft or disintegrated stone, dirt, or other objectionable matter, occurring either free or as a coating on the stone.

**Physical properties.**

The stone shall meet the following requirements:

Per cent of wear-----not more than -----  
 (or French coefficient-----not less than -----.)  
 \*Hardness-----not less than -----  
 \*Toughness-----not less than -----  
 \*Absorption-----not more than -----%

**Grading.**

The broken stone aggregate, when tested by means of laboratory screens, shall meet the following requirements:

\* Tests recommended by the conference, which it may be desirable to omit in some instances.



|                                                                                                                      |                |
|----------------------------------------------------------------------------------------------------------------------|----------------|
| Passing (the largest size selected) inch screen                                                                      | Per cent.      |
| Passing (the largest size selected) inch screen                                                                      | 100            |
| and retained on (the second largest size selected) inch screen                                                       | ----- to ----- |
| Passing (the second largest size selected) inch screen and retained on (the third largest size selected) inch screen | ----- to ----- |
| Passing (the third largest size selected) inch screen and retained on (the fourth largest size selected) inch screen | ----- to ----- |
| *Passing, etc                                                                                                        | -----          |

Stone shall be sampled for quality and grading in accordance with the method described on page -----, paragraphs -----, of these specifications.

Method of sampling.

Tests of the physical properties and grading of the stone shall be made in accordance with the methods described or referred to on pages ----- of these specifications, tests Nos. -----

Methods of testing.

### SPECIFICATION FOR COARSE AND FINE AGGREGATE FOR LARGE AGGREGATE BITUMINOUS CONCRETE (BROKEN STONE OR SAND).

#### BROKEN STONE FOR COARSE AGGREGATE.

The broken stone for coarse aggregate shall consist of angular fragments of ----- (insert types allowable) -----, free from thin or elongated pieces, soft or disintegrated stone, dirt, or other objectionable matter occurring either free or as a coating on the stone.

General.

The stone shall meet the following requirements:

|                        |                             |
|------------------------|-----------------------------|
| Per cent of wear       | ----- not more than -----   |
| (or French coefficient | ----- not less than -----.) |
| † Hardness             | ----- not less than -----   |
| † Toughness            | ----- not less than -----   |
| † Absorption           | ----- not more than ----- % |

Physical properties.

The broken stone for coarse aggregate, when tested by means of laboratory screens, shall meet the following requirements:

Grading.

|                                                                 |                |
|-----------------------------------------------------------------|----------------|
| Passing (the largest size selected) -inch screen                | Per cent.      |
| Passing (the largest size selected) -inch screen                | 100            |
| and retained on (the second largest size selected) -inch screen | ----- to ----- |
| †Passing, etc                                                   | -----          |

Stone shall be sampled for quality and grading in accordance with the method described on page -----, paragraphs -----, of these specifications.

Method of sampling.

\* The number and size of screens and sieves may be continued as desired by the engineer. For 10-mesh sieve and finer the wording should be: Passing ----- mesh sieve and retained on ----- mesh sieve to ----- The last requirement should be: Passing ----- inch screen (or mesh sieve) not more than (or not less than) -----.

† Tests recommended by the conference which it may be desirable to omit in some instances.

‡ The number and sizes of screens may be continued as desired by the engineer. The last requirement should be: Passing 1/4-inch screen, not more than -----.

**Methods of testing.**

Tests of the physical properties and grading of the stone shall be made in accordance with the methods described or referred to on pages ----- of these specifications, tests Nos. -----.

**BROKEN STONE OR SAND FOR FINE AGGREGATE.****General.**

The fine aggregate shall be composed of sound, durable particles of stone or sand. The particles shall be free from a coating of clay or loam.

**Grading.**

The broken stone or sand for fine aggregate, when tested by means of laboratory screens and sieves, shall meet the following requirements:

|                                                            | Per cent.      |
|------------------------------------------------------------|----------------|
| Passing 1/4-inch screen-----not less than                  | -----          |
| Passing 1/4-inch screen and retained on 10-mesh sieve----- | ----- to ----- |
| Passing 10-mesh and retained on 40-mesh sieve -----        | ----- to ----- |
| Passing 40-mesh and retained on 200-mesh sieve -----       | ----- to ----- |
| Passing 200-mesh sieve-----not more than                   | -----          |

**Methods of sampling and grading.**

Stone or sand shall be sampled for grading in accordance with the methods described on page -----, paragraphs -----, of these specifications, and tests of grading shall be made in accordance with the method described or referred to on page ----- of these specifications, test No. -----.

**SPECIFICATION FOR COARSE AND FINE AGGREGATE FOR TOPEKA TYPE BITUMINOUS CONCRETE (BROKEN STONE OR SAND).****BROKEN STONE FOR COARSE AGGREGATE.****General.**

The broken stone for coarse aggregate shall consist of angular fragments of (insert types allowable), free from thin or elongated pieces, soft or disintegrated stone, dirt, or other objectionable matter, occurring either free or as a coating on the stone.

**Physical properties.**

The stone shall meet the following requirements:

|                                           |        |
|-------------------------------------------|--------|
| Per cent of wear-----not more than        | -----  |
| (or French coefficient-----not less than) | -----) |
| *Hardness-----not less than               | -----  |
| *Toughness-----not less than              | -----  |
| *Absorption-----not more than             | -----% |

**Grading.**

The broken stone for coarse aggregate, when tested by means of laboratory screens, shall meet the following requirements:

|                                                                                                                     | Per cent.      |
|---------------------------------------------------------------------------------------------------------------------|----------------|
| Passing (the largest size selected) inch screen-----                                                                | 100            |
| Passing (the largest size selected) inch screen and retained on (the second largest size selected) inch screen----- | ----- to ----- |
| †Passing, etc-----                                                                                                  | -----          |

\* Tests recommended by the conference, which it may be desirable to omit in some instances.

† The number and sizes of screens may be continued as desired by the engineer. The last requirement should be: Passing 10-mesh sieve, not more than -----.

Stone shall be sampled for quality and grading in accordance with the method described on page \_\_\_\_\_, paragraphs \_\_\_\_\_, of these specifications.

Method of sampling.

Tests of the physical properties and grading of the stone shall be made in accordance with the methods described on pages \_\_\_\_\_ of these specifications, tests Nos. \_\_\_\_\_.

Methods of testing.

BROKEN STONE OR SAND FOR FINE AGGREGATE.

The fine aggregate shall be composed of sound, durable particles of stone or sand. The particles shall be free from a coating of clay or loam.

General.

The broken stone or sand for fine aggregate, when tested by means of laboratory sieves, shall meet the following requirements:

Grading.

|                                                      |               |           |
|------------------------------------------------------|---------------|-----------|
| Passing 10-mesh sieve.....                           | not less than | Per cent. |
| Passing 10-mesh and retained on 40-mesh sieve .....  | -----         | -----     |
| Passing 40-mesh and retained on 80-mesh sieve .....  | -----         | to -----  |
| Passing 80-mesh and retained on 200 mesh sieve ..... | -----         | to -----  |
| Passing 200-mesh sieve.....                          | -----         | to -----  |

Stone or sand shall be sampled for grading in accordance with the method described on page \_\_\_\_\_, paragraphs \_\_\_\_\_, of these specifications, and tests of grading shall be made in accordance with the method described or referred to on page \_\_\_\_\_ of these specifications, test No. \_\_\_\_\_.

Methods of sampling and grading.

SPECIFICATION FOR BROKEN STONE OR GRAVEL FOR COARSE AGGREGATE FOR PORTLAND-CEMENT CONCRETE BASE.

The broken stone or gravel aggregate shall consist of clean, hard, tough, durable rock. It shall contain no vegetable or other deleterious matter, and shall be free from soft, thin, elongated or laminated pieces.

General.

The broken stone or gravel shall be graded from coarse to fine, and when tested by means of laboratory screens shall meet the following requirements:

Grading.

|                                |                     |
|--------------------------------|---------------------|
| Passing _____ inch screen..... | Per cent.           |
| Passing _____ inch screen..... | 100                 |
| Passing _____ inch screen..... | not more than ----- |

Broken stone or gravel shall be sampled for grading in accordance with the method described on page \_\_\_\_\_, paragraphs \_\_\_\_\_, of these specifications, and tests of grading shall be made in accordance with the method described or referred to on page \_\_\_\_\_ of these specifications, test No. \_\_\_\_\_.

Methods of sampling and grading.

SPECIFICATION FOR BROKEN STONE FOR COARSE AGGREGATE FOR PORTLAND-CEMENT CONCRETE WEARING SURFACE.

The broken stone aggregate shall consist of fragments of clean, hard, tough, durable rock. It shall contain no vegetable or other deleterious matter, and shall be free from soft, thin, elongated, or laminated pieces.

General.



**Physical properties.**

The stone shall meet the following requirement:

Per cent of wear-----not more than -----  
(or French coefficient-----not less than -----)

**Grading.**

The broken stone, when tested by means of laboratory screens, shall meet the following requirements:

|                                             |                |
|---------------------------------------------|----------------|
| Passing ----- inch screen-----              | Per cent.      |
| Passing -----* inch screen and retained     | 100            |
| on ----- inch screen-----                   | ----- to ----- |
| Passing ----- inch screen-----not more than | -----          |

**Method of sampling.**

Stone shall be sampled for quality and grading in accordance with the method described on page -----, paragraphs -----, of these specifications.

**Methods of testing.**

Tests of the physical properties and grading of the stone shall be made in accordance with the methods described or referred to on pages ----- of these specifications, tests Nos. -----.

**SPECIFICATION FOR STONE OR GRAVEL SCREENINGS FOR FINE AGGREGATE FOR PORTLAND-CEMENT CONCRETE BASE.**

**General.**

The screenings shall consist of material obtained by crushing hard, durable rock or gravel, all of which shall pass a revolving screen having circular openings three-eighths of an inch in diameter. They shall be free from lumps of clay and at the time of use from lumps or crusts of hardened material.

**Physical properties.**

If the screenings are produced from rock, the rock shall meet the following requirement:

Per cent of wear-----not more than -----  
(or French coefficient-----not less than -----)

**Grading.**

The screenings shall be well graded from coarse to fine and when tested by means of laboratory screens and sieves shall meet the following requirements:

|                                                      |                |
|------------------------------------------------------|----------------|
| Passing $\frac{1}{4}$ -inch screen-----not less than | Per cent.      |
| Passing 20-mesh and retained on 50-mesh              | -----          |
| sieve-----                                           | ----- to ----- |
| Passing 100-mesh sieve-----not more than             | -----          |

**Mortar strength tests.**

When that portion of the screenings which passes a one-quarter inch laboratory screen is mixed with Portland cement in the proportions of 1 part of cement to 3 parts of screenings, by weight, according to standard methods of making 1:3 mortar briquets, the resulting mortar at the age of 7 and 28 days shall have a tensile strength of at least ----- $\dagger$  per cent of the strength developed in the same time by mortar of the same proportions made of the same cement and Ottawa sand.

Preliminary acceptance samples shall be subjected to both 7 and 28 day tests and acceptance based thereupon. Samples tested during the progress of the work will be accepted on the basis of the 7-day test.

**Method of sampling.**

Stone shall be sampled for quality in accordance with the method described on page -----, paragraphs -----, of these

\* It is recommended that a  $\frac{3}{4}$ -inch screen be specified here.

$\dagger$  It is recommended that the minimum strength ratio be 90 per cent for this purpose.

specifications. Stone or gravel screenings shall be sampled for grading in accordance with the method described on page -----, paragraphs -----; of these specifications.

Tests of the physical properties of stone shall be made in accordance with the method described or referred to on page ----- of these specifications, test No. ----- Tests of the grading of screenings shall be made in accordance with the method described or referred to on page ----- of these specifications, test No. -----.

Methods of testing.

#### SPECIFICATION FOR COMBINATIONS OF DUSTLESS SCREENINGS AND SAND FOR FINE AGGREGATE FOR PORTLAND-CEMENT CONCRETE WEARING SURFACE.

The fine aggregate may be composed of a combination of dustless screenings and sand, but shall contain not more than -----\* per cent, by volume, of dustless screenings.

General.

The dustless screenings shall consist of material obtained by crushing hard, durable rock, or gravel, all of which when dry shall pass a revolving screen having circular openings three-eighths-inch in diameter. They shall be free from lumps of clay and, at the time of use, from lumps or crusts of hardened material.

The sand shall consist of clean, hard, durable, uncoated particles, preferably siliceous, well graded from coarse to fine, and free from lumps of clay and all organic matter.

If the dustless screenings are produced from rock, the rock shall meet the following requirement:

Physical properties, dustless screenings.

Per cent of wear-----not more than -----  
(or French coefficient-----not less than -----)

The dustless screenings shall be well graded from coarse to fine, and, when tested by means of laboratory screens and sieves, shall meet the following requirements:

Grading of dustless screenings.

Per cent.  
Passing 1/4-inch screen-----not less than -----  
Passing 20-mesh and retained on 50-mesh  
sieve-----to -----  
Passing 100-mesh sieve-----not more than 5

The mixture of screenings and sand shall contain no particles which would not pass a revolving screen having circular openings not greater than three-eighths-inch in diameter. When tested by means of laboratory screens and sieves it shall meet the following requirements:

Grading of mixture.

Per cent.  
Passing 1/4-inch screen-----not less than -----  
Passing 20-mesh and retained on 50-mesh  
sieve-----to -----  
†Total passing 50-mesh sieve-----not more than -----  
‡Passing 100-mesh sieve-----not more than -----  
Not more than ----- per cent by weight shall be removed by the elutriation test.

\* The figure 50 is recommended.

† It is recommended that 25 per cent be specified as the amount permitted to pass a 50-mesh sieve.

‡ It is recommended that 5 per cent be specified as the quantity permitted to pass a 100-mesh sieve.

**M o r t a r  
strength test.**

When that portion of the combined dustless screenings and sand which passes a one-quarter-inch laboratory screen is mixed with Portland cement in the proportion of 1 part of cement to 3 parts of the combination, by weight, according to standard methods of making 1:3 mortar briquets, the resulting mortar at the age of 7 and 28 days shall have a tensile strength of at least -----\* per cent of that developed in the same time by mortar of the same proportions and consistency, made of the same cement and Ottawa sand.

Preliminary acceptance samples shall be subjected to both 7 and 28-day tests, and acceptance based thereupon. Samples tested during the progress of the work will be accepted on the basis of the 7-day test.

**Methods of  
sampling.**

Stone shall be sampled for quality in accordance with the method described on page -----, paragraphs -----, of these specifications. Dustless screenings and mixtures of the dustless screenings and sand shall be sampled for grading in accordance with the method described on page -----, paragraphs -----, of these specifications; and sand shall be sampled in accordance with the method described on page -----, paragraphs -----, of these specifications.

**Methods of  
testing.**

Tests of the physical properties of stone shall be made in accordance with the method described or referred to on page ----- of these specifications, test No. -----. Tests of the grading of dustless screenings and of the combination of dustless screenings and sand shall be made in accordance with the method described or referred to on page ----- of these specifications, test No. -----.

NOTE.—It is recommended that volumetric analyses be reported by the laboratory to facilitate field control.

**SPECIFICATION FOR STONE BLOCK.****General.**

The stone block shall be of (insert types allowable), of medium-sized grain, showing an even distribution of constituent minerals. They shall be of uniform quality and texture throughout, and free from seams, scales, or disintegrated material.

**Physical prop-  
erties.**

Sample blocks shall meet the following requirements:

Per cent of wear-----not more than -----  
(or French coefficient-----not less than -----)

Hardness-----to -----

**Dimensions.**

The blocks shall meet the following requirements:

Length on top-----Inches.  
-----to -----

Width on top-----to -----

Depth-----to -----

**Visual inspec-  
tion.**

The stone block shall be subjected to inspection subsequent to delivery at the place of use, prior to and during laying, in order to cull out and reject those which fail to conform with the general

\* It is recommended that the strength ratio be 100 per cent for this purpose.



and dimension clauses and the following requirements of this specification.\*

The blocks shall be so dressed that when laid as specified measurement of any joint shall show a width of not more than \_\_\_\_\_ inch for a depth of \_\_\_\_\_ inches or a width of not more than \_\_\_\_\_ inch in any part of the joint.

The wearing surface of the blocks shall show no depressions more than \_\_\_\_\_ inch deep, and the edges and corners shall be unchipped and unbroken.

Stone block shall be sampled in accordance with the methods described on page \_\_\_\_\_, paragraph \_\_\_\_\_, of these specifications, and tests of physical properties shall be made in accordance with the methods described or referred to on pages \_\_\_\_\_ of these specifications, tests Nos. \_\_\_\_\_.

Methods of  
sampling and  
testing.

#### SPECIFICATION FOR BROKEN SLAG FOR WATER BOUND MACADAM.

The broken slag shall consist of angular fragments of (insert types allowable) slag, reasonably uniform in density and quality, free from metallic iron, thin or elongated pieces, dirt, or other objectionable matter.

General.

The slag shall meet the following requirements:

Weight per cubic foot \_\_\_\_\_ not less than \_\_\_\_\_ pounds.

Per cent of wear \_\_\_\_\_ to \_\_\_\_\_

(or French coefficient \_\_\_\_\_ to \_\_\_\_\_)

Physical prop-  
erties.

That portion of the product of the crusher, including the dust of fracture, which, when tested by means of laboratory screens, will meet the following requirements:

Passing \_\_\_\_\_ inch screen \_\_\_\_\_ Per cent. 100

Total passing \_\_\_\_\_ inch screen \_\_\_\_\_ to \_\_\_\_\_

Screenings or  
No. -- slag.

That portion of the product of the crusher which, when tested by means of laboratory screens, will meet the following requirements:

Passing \_\_\_\_\_ inch screen \_\_\_\_\_ Per cent. 100

Total passing \_\_\_\_\_ inch screen \_\_\_\_\_ to \_\_\_\_\_

Retained on \_\_\_\_\_ inch screen \_\_\_\_\_ 100

Top course or  
No. -- slag.

That portion of the product of the crusher which, when tested by means of laboratory screens, will meet the following requirements:

Passing \_\_\_\_\_ inch screen \_\_\_\_\_ Per cent. 100

Total passing \_\_\_\_\_ inch screen \_\_\_\_\_ to \_\_\_\_\_

Retained on \_\_\_\_\_ inch screen \_\_\_\_\_ 100

Bottom course  
or No. -- slag.

The slag shall be sampled for quality and size in accordance with the method described on page \_\_\_\_\_, paragraphs \_\_\_\_\_, of these specifications.

Method of sam-  
pling.

The tests of the physical properties and sizes of the slag shall be made in accordance with the methods described or referred to on pages \_\_\_\_\_ of these specifications, tests Nos. \_\_\_\_\_.

Methods of  
testing.

\*This sentence has been inserted as a matter of editing, in order to make the requirements conform in principle with the specification for brick recommended by the conference.

## SPECIFICATION FOR BROKEN SLAG FOR BITUMINOUS MACADAM.

|                                          |                                                                                                                                                                                                                                                                                        |                  |
|------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| <b>General.</b>                          | The broken slag shall consist of angular fragments of<br>(insert types allowable) slag, reasonably uniform in<br>density and quality, free from metallic iron, thin or elongated<br>pieces, dirt, or other objectionable matter, occurring either free<br>or as a coating on the slag. |                  |
| <b>Physical prop-<br/>erties.</b>        | The slag shall meet the following requirements:<br>Weight per cubic foot-----not less than ----- pounds.<br>Per cent of wear-----not more than -----<br>(or French coefficient-----not less than -----)                                                                                |                  |
| <b>Chips or<br/>No. -- slag.</b>         | That portion of the product of the crusher which, when tested<br>by means of laboratory screens, will meet the following require-<br>ments:                                                                                                                                            |                  |
|                                          | Passing -----inch screen-----                                                                                                                                                                                                                                                          | Per cent.<br>100 |
|                                          | Total passing -----inch screen----- to -----                                                                                                                                                                                                                                           |                  |
|                                          | Retained on -----inch screen-----                                                                                                                                                                                                                                                      | 100              |
| <b>Top course or<br/>No. -- slag.</b>    | That portion of the product of the crusher which, when tested<br>by means of laboratory screens, will meet the following require-<br>ments:                                                                                                                                            |                  |
|                                          | Passing -----inch screen-----                                                                                                                                                                                                                                                          | Per cent.<br>100 |
|                                          | Total passing -----inch screen----- to -----                                                                                                                                                                                                                                           |                  |
|                                          | Retained on -----inch screen-----                                                                                                                                                                                                                                                      | 100              |
| <b>Bottom course<br/>or No. -- slag.</b> | That portion of the product of the crusher which, when tested<br>by means of laboratory screens, will meet the following require-<br>ments:                                                                                                                                            |                  |
|                                          | Passing -----inch screen-----                                                                                                                                                                                                                                                          | Per cent.<br>100 |
|                                          | Total passing -----inch screen----- to -----                                                                                                                                                                                                                                           |                  |
|                                          | Retained on -----inch screen-----                                                                                                                                                                                                                                                      | 100              |
| <b>Method of sam-<br/>pling.</b>         | Slag shall be sampled for quality and size in accordance with<br>the method described on page -----, paragraphs -----, of these<br>specifications.                                                                                                                                     |                  |
| <b>Methods of<br/>testing.</b>           | Tests of the physical properties and sizes of the slag shall be<br>made in accordance with the methods described or referred to on<br>pages ----- of these specifications, tests Nos. -----.                                                                                           |                  |

SPECIFICATION FOR BROKEN SLAG AGGREGATE FOR LARGE AGGREGATE  
BITUMINOUS CONCRETE.

|                                   |                                                                                                                                                                                                                                                                                                  |                  |
|-----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| <b>General.</b>                   | The broken slag aggregate shall consist of angular fragments of<br>(insert types allowable) slag, reasonably uniform in density and<br>quality, free from metallic iron, thin or elongated pieces, dirt, or<br>other objectionable matter, occurring either free or as a coating<br>on the slag. |                  |
| <b>Physical prop-<br/>erties.</b> | The slag shall meet the following requirements:<br>Weight per cubic foot-----not less than ----- pounds<br>Per cent of wear-----not more than -----<br>(or French coefficient-----not less than -----)                                                                                           |                  |
| <b>Grading.</b>                   | The broken slag aggregate, when tested by means of laboratory<br>screens, shall meet the following requirements:                                                                                                                                                                                 |                  |
|                                   | Passing (the largest size selected) inch screen-----                                                                                                                                                                                                                                             | Per cent.<br>100 |

Per cent.

Passing (the largest size selected) inch screen  
and retained on (the second largest size  
selected) inch screen ----- to -----

Passing (the second largest size selected) inch  
screen and retained on (the third largest  
size selected) inch screen ----- to -----

\*Passing, etc. -----

Slag shall be sampled for quality and grading in accordance  
with the method described on page -----, paragraphs -----, of  
these specifications.

Method of sam-  
pling.

Tests of the physical properties and grading of the slag shall be  
made in accordance with the methods described or referred to on  
pages ----- of these specifications, tests Nos. -----.

Methods of  
testing.

#### SPECIFICATION FOR BROKEN SLAG FOR COARSE AGGREGATE FOR PORTLAND- CEMENT CONCRETE BASE.

The broken slag aggregate shall consist of fragments of air-cooled  
(insert types allowable) slag, nonglassy in character, which shall  
have been exposed to the weather for a period of at least -----†  
prior to use. It shall be clean, hard, tough, and durable, free  
from soft, thin, elongated, or laminated pieces, and shall contain  
no vegetable or other deleterious matter.

General.

The slag shall meet the following requirement:

Physical prop-  
erties.

Weight per cubic foot ----- not less than ----- pounds.

Grading.

The broken slag aggregate shall be graded from coarse to fine,  
and when tested by means of laboratory screens shall meet the  
following requirements:

Per cent.

Passing ----- inch screen ----- 100

Passing ----- inch screen ----- not more than -----

The slag shall be sampled for quality and grading in accordance  
with the method described on page -----, paragraphs -----,  
of these specifications.

Method of sam-  
pling.

The tests of the physical properties and grading of the slag  
shall be made in accordance with the methods described or re-  
ferred to on pages ----- of these specifications, tests Nos. -----.

Methods of  
testing.

#### SPECIFICATION FOR GRANULATED SLAG FOR CUSHION.

The granulated slag shall consist of clean, sharp, gritty parti-  
cles of water-cooled (insert types allowable) slag, all of which shall  
pass a ----- inch laboratory screen.

General.

The granulated slag shall be sampled for quality and size in  
accordance with the method described on page -----, paragraphs  
-----, of these specifications; and the tests of its size shall be  
made in accordance with the method described or referred to on  
page ----- of these specifications, test No. -----.

Methods of  
sampling and  
grading.

\* The number and sizes of screens and sieves may be continued as de-  
sired by the engineer. For 10-mesh sieve and finer the wording should be:  
Passing ----- mesh sieve and retained on ----- mesh sieve, ----- to  
----- The last requirement should be: Passing ----- inch screen  
(or mesh sieve) not more than (or, not less than) -----.

† The conference recommends that the words "one year" be inserted.



## SPECIFICATION FOR GRAVEL FOR PLAIN GRAVEL ROADS.

## General.

The gravel shall be composed of hard, durable rock, of high resistance to abrasion,\* together with sand and clay or other binding material, and shall be free from thin or elongated pieces.

## Grading.

## 1. For base course:

- (a) The gravel, when tested by means of laboratory screens, shall meet the following requirements:

|                                        |                |
|----------------------------------------|----------------|
| Passing a -----inch screen-----        | Per cent.      |
| Total retained on 1/4-inch screen----- | 100            |
|                                        | ----- to ----- |

- (b) The material retained on the 1/4-inch screen is known as coarse aggregate. The coarse aggregate, when tested by means of a laboratory screen, shall meet the following requirement:

|                                          |                |
|------------------------------------------|----------------|
| Total retained on -----inch screen ----- | ----- to ----- |
|------------------------------------------|----------------|

- (c) The material passing the 1/4-inch screen is known as fine aggregate. The fine aggregate, when tested by means of a laboratory sieve, shall meet the following requirement:

|                                   |                |
|-----------------------------------|----------------|
| Total passing 200-mesh sieve----- | ----- to ----- |
|-----------------------------------|----------------|

## 2. For wearing course:

- (a) The gravel, when tested by means of laboratory screens, shall meet the following requirements:

|                                        |                |
|----------------------------------------|----------------|
| Passing a -----inch screen-----        | 100            |
| Total retained on 1/4-inch screen----- | ----- to ----- |

- (b) The material retained on the 1/4-inch screen is known as coarse aggregate. The coarse aggregate, when tested by means of a laboratory screen, shall meet the following requirement:

|                                          |                |
|------------------------------------------|----------------|
| Total retained on -----inch screen ----- | ----- to ----- |
|------------------------------------------|----------------|

- (c) The material passing the 1/4-inch screen is known as fine aggregate. The fine aggregate, when tested by

---

\* The conference believes it highly desirable to specify definite test limits for the resistance of gravel to abrasion. The only State which has so far extensively employed an abrasion test for gravel is Ohio. Available test records, therefore, cover only gravels used in that State; and it is felt that sufficient data have not been obtained as yet to warrant the use of an abrasion test clause in the gravel specifications of other States. The conference recommends that individual States make use of the Ohio test for the purpose of establishing limits which may be used later in specifying satisfactory gravels which are available for their highway work. A description of this test will be found on page 30.

Per cent.

means of a laboratory sieve, shall meet the following requirement:

Total passing 200-mesh sieve----- to -----

The gravel shall be sampled for quality and grading in accordance with the method described on page -----, paragraphs -----, of these specifications; and the grading of the gravel shall be determined in accordance with the method described or referred to on page ----- of these specifications, test No. -----

Methods of  
sampling and  
testing.

#### SPECIFICATION FOR GRAVEL AGGREGATE FOR LARGE AGGREGATE BITUMINOUS CONCRETE.

The gravel aggregate shall consist of sound, hard, durable rock, of high resistance to abrasion,\* and shall contain no particles of shale, slate, coal, or other materials which easily disintegrate. It shall be free from vegetable or other deleterious matter, and shall contain no soft, thin, or elongated pieces.

General.

The gravel aggregate, when tested by means of laboratory screens, shall meet the following requirements:

Grading.

Per cent.  
100

Passing (the largest size selected) inch screen-----  
Passing (the largest size selected) inch screen  
and retained on (the second largest size  
selected) inch screen----- to -----  
Passing (the second largest size selected) inch  
screen and retained on (the third largest  
size selected) inch screen----- to -----  
†Passing, etc.-----

The gravel shall be sampled for quality and grading in accordance with the method described on page -----, paragraphs -----, of these specifications; and the grading shall be determined in accordance with the method described or referred to on page ----- of these specifications, test No. -----

Methods of  
sampling and  
grading.

#### SPECIFICATION FOR GRAVEL FOR COARSE AGGREGATE FOR PORTLAND-CEMENT CONCRETE WEARING SURFACE.

The gravel aggregate shall consist of sound, hard, durable rock of high resistance to abrasion,\* and shall contain no particles of shale, slate, coal, or other materials which easily disintegrate. It shall be free from vegetable or other deleterious matter, and shall contain no soft, thin, or elongated pieces.

General.

\*The conference believes it highly desirable to specify definite test limits for the resistance of gravel to abrasion. The only State which has so far extensively employed an abrasion test for gravel is Ohio. Available test records, therefore, cover only gravels used in that State, and it is felt that sufficient data have not been obtained as yet to warrant the use of an abrasion-test clause in the gravel specifications of other States. The conference recommends that individual States make use of the Ohio test for the purpose of establishing limits which may be used later in specifying satisfactory gravels which are available for their highway work. A description of this test will be found on page 30.

†The number and sizes of screens and sieves may be continued as desired by the engineer. For 10-mesh sieve and finer, the wording should be: Passing ----- mesh sieve and retained on ----- mesh sieve, ----- to ----- The last requirement should be: Passing ----- inch screen (or mesh sieve) not more than (or not less than) -----

Grading.

The gravel aggregate, when tested by means of laboratory screens, shall meet the following requirements:

Per cent.

Passing ----- inch screen----- 100

Passing ----- inch screen and retained on 1/4-inch screen----- to -----

Passing 1/4-inch screen-----not more than -----

Methods of sampling and grading.

The gravel shall be sampled for quality and grading in accordance with the method described on page -----, paragraphs -----, of these specifications; and the grading shall be determined in accordance with the method described or referred to on page ----- of these specifications, test No. -----.

SPECIFICATION FOR SEMIGRAVEL, TOP-SOIL, OR SAND-CLAY AGGREGATE FOR ROAD SURFACING.

Definitions.

The terms *clay*, *silt*, *sand*, and *coarse material*, used in this specification, are defined as follows:\*

Clay: Material separated by subsidence through water and possessing plastic or adhesive properties, generally below 0.01 mm. diameter.

Silt: Fine material, other than clay, which passes a 200-mesh sieve, generally from 0.07 to 0.01 mm. diameter.

Sand: Hard material, usually siliceous, which passes a 10-mesh sieve and is retained on a 200-mesh sieve, generally from 1.85 to 0.07 mm. diameter.

Coarse material: Hard material of gravelly nature, retained on a 10-mesh sieve, i. e., more than 1.85 mm. diameter.

Physical properties, coarse material.

The coarse material, if any, of the aggregate, shall consist of hard, siliceous material, free from feldspar, mica, schist, hardpan, or other soft, friable material, in excess of 5 per cent.

Mechanical analysis of material passing 10-mesh sieve.

The material which will pass a 10-mesh sieve, when subjected to mechanical analysis, shall meet the following requirements:

Per cent.

Clay----- to -----

Silt----- to -----

Total sand----- to -----

Sand retained on 60-mesh sieve----- to -----

Methods of sampling and testing.

The material shall be sampled in accordance with the method described on pages -----, paragraphs -----, of these specifications; and the mechanical analysis shall be made in accordance with the methods described or referred to on page ----- of these specifications, tests Nos. -----.

NOTE.—To cover the range of materials adaptable for road construction, it is recommended that roads of these types be divided into three classes, designated, Hard or Class A, Medium or Class B, and Soft or Class C, according to the mechanical analysis of the material which is to be specified for use. The limiting percentages of the constituents suggested for the three classes are as follows:

|                                     | Hard or Class A. | Medium or Class B. | Soft or Class C. |
|-------------------------------------|------------------|--------------------|------------------|
|                                     | Per cent.        | Per cent.          | Per cent.        |
| Clay-----                           | 9 to 15          | 15 to 25           | 10 to 25         |
| Silt-----                           | 5 to 15          | 10 to 20           | 10 to 20         |
| Total sand-----                     | 65 to 80         | 60 to 70           | 55 to 80         |
| Sand retained on 60-mesh sieve----- | 45 to 60         | 30 to 45           | 15 to 30         |

\* The definitions here given are intended to apply to these terms only when used in connection with roads of these types.



**SPECIFICATION FOR SAND FOR SHEET ASPHALT.**

The sand shall be composed of sound, durable particles, free from a coating of clay or loam.

General.

When tested by means of laboratory sieves, it shall meet the following requirements:

Grading.

|                                                      | Per cent.      |
|------------------------------------------------------|----------------|
| Passing 10-mesh sieve-----not less than              | -----          |
| Passing 10-mesh and retained on 40-mesh sieve -----  | ----- to ----- |
| Passing 40-mesh and retained on 80-mesh sieve -----  | ----- to ----- |
| Passing 80-mesh and retained on 200-mesh sieve ----- | ----- to ----- |
| Passing 200-mesh sieve -----                         | ----- to ----- |

The sand shall be sampled for grading in accordance with the method described on page -----, paragraphs -----, of these specifications; and tests of grading shall be made in accordance with the method described or referred to on page ----- of these specifications, test No. -----.

Methods of sampling and grading.

NOTE.—It is recommended that volumetric analyses be reported by the laboratory to facilitate field control.

**SPECIFICATION FOR SAND FOR FINE AGGREGATE FOR PORTLAND-CEMENT CONCRETE BASE.**

The sand shall consist of clean, hard, durable, uncoated particles, preferably siliceous, free from lumps of clay and all organic matter.

General.

It shall be well graded from coarse to fine and, when tested by means of laboratory screens and sieves, shall meet the following requirements:

Grading.

|                                                                                  | Per cent.      |
|----------------------------------------------------------------------------------|----------------|
| Passing 1/4-inch screen-----                                                     | 100            |
| Passing 20-mesh and retained on 50-mesh sieve -----                              | ----- to ----- |
| *Passing 50-mesh sieve-----not more than                                         | -----          |
| Not more than ----- per cent by weight shall be removed by the elutriation test. |                |

When the sand is mixed with Portland cement in the proportion of 1 part of cement to 3 parts of sand, by weight, according to standard methods of making 1:3 mortar briquets, the resulting mortar at the age of 7 and 28 days shall have a tensile strength of at least -----† per cent of that developed in the same time by mortar of the same proportions and consistency, made of the same cement and Ottawa sand.

Mortar strength test.

Preliminary acceptance samples shall be subjected to both 7 and 28-day tests, and acceptance based thereupon. Samples tested during the progress of the work will be accepted on the basis of the 7-day test.

\* It is recommended that the amount passing the 50-mesh sieve be limited to 30 per cent, or less, if practicable.

† It is recommended that the minimum strength ratio for this purpose be 70 per cent, or greater, if possible under existing conditions; and that where sands giving a 70 per cent strength ratio are not available the proportion of cement be increased so as to give that percentage.

**Methods of  
sampling and  
grading.**

The sand shall be sampled in accordance with the method described on page -----, paragraphs -----, of these specifications; and the grading shall be determined in accordance with the methods described or referred to on page ----- of these specifications, tests Nos. -----.

NOTE.—It is recommended that volumetric analyses be reported by the laboratory to facilitate field control.

**SPECIFICATION FOR SAND FOR FINE AGGREGATE FOR PORTLAND-CEMENT  
CONCRETE WEARING SURFACE.**

**General.**

The sand shall consist of clean, hard, durable, uncoated particles, preferably siliceous, free from lumps of clay and all organic matter.

**Grading.**

It shall be well graded from coarse to fine, and when tested by means of laboratory screens and sieves shall meet the following requirements:

|                            |           |
|----------------------------|-----------|
| Passing ¼-inch screen----- | Per cent. |
|                            | 100       |

|                                                       |          |
|-------------------------------------------------------|----------|
| Passing 20-mesh and retained on 50-mesh<br>sieve----- | to ----- |
|-------------------------------------------------------|----------|

|                                                  |       |
|--------------------------------------------------|-------|
| *Total passing 50-mesh sieve not more than ----- | ----- |
|--------------------------------------------------|-------|

|                              |                     |
|------------------------------|---------------------|
| †Passing 100-mesh sieve----- | not more than ----- |
|------------------------------|---------------------|

Not more than ----- per cent by weight shall be removed by the elutriation test.

**M o r t a r  
strength test.**

When the sand is mixed with Portland cement in the proportion of 1 part of cement to 3 parts of sand, by weight, according to standard methods of making 1:3 mortar briquets, the resulting mortar at the age of 7 and 28 days shall have a tensile strength of at least ----- ‡ per cent of that developed in the same time by mortar of the same proportions and consistency, made of the same cement and Ottawa sand.

Preliminary acceptance samples shall be subjected to both 7 and 28 day tests, and acceptance based thereupon. Samples tested during the progress of the work will be accepted on the basis of the 7-day test.

**Methods of  
sampling and  
grading.**

The sand shall be sampled in accordance with the method described on page -----, paragraphs -----, of these specifications; and the grading shall be determined in accordance with the methods described or referred to on page ----- of these specifications, tests Nos. -----.

NOTE.—It is recommended that volumetric analyses be reported by the laboratory to facilitate field control.

**SPECIFICATION FOR GROUTING SAND.**

**General.**

The sand shall consist of clean, hard, durable, uncoated particles, preferably siliceous, free from lumps of clay and all organic matter.

\* It is recommended that 25 per cent be specified as the amount permitted to pass a 50-mesh sieve, and in localities where practicable that a smaller figure be used.

† It is recommended that 5 per cent be specified as the quantity permitted to pass.

‡ It is recommended that the strength ratio be 100 per cent for this purpose.

It shall be well graded from coarse to fine and, when tested by means of laboratory screens, shall meet the following requirements:

Grading.

Per cent.

Passing -----\* mesh sieve-----not less than -----†

Passing 100-mesh sieve-----not more than -----

Not more than ----- per cent by weight shall be removed by the elutriation test.

When the sand is mixed with Portland cement in the proportions of 1 part of cement to 3 parts of sand by weight, according to standard methods of making 1:3 mortar briquets, the resulting mortar at the age of 7 and 28 days shall have a tensile strength of at least -----‡ per cent of that developed in the same time by mortar of the same proportions and consistency, made of the same cement and Ottawa sand.

Mortar  
strength test.

Preliminary acceptance samples shall be subjected to both 7 and 28 day tests, and acceptance based thereupon. Samples tested during the progress of the work will be accepted on the basis of the 7-day test.

The sand shall be sampled in accordance with the method described on page -----, paragraphs -----, of these specifications; and the grading shall be determined in accordance with the methods described, or referred to, on page ----- of these specifications, tests Nos. -----.

Methods of  
sampling and  
grading.

NOTE.—It is recommended that volumetric analyses be reported by the laboratory to facilitate field control.

#### SPECIFICATION FOR SAND FOR CUSHION.

The sand shall pass a ----- inch laboratory screen, and not less than ----- per cent shall pass a 20-mesh sieve. The material removed by the elutriation test, consisting chiefly of clay and loam, shall not exceed ----- per cent by weight.

Grading.

The sand shall be sampled in accordance with the method described on page -----, paragraphs -----, of these specifications; and the grading shall be determined in accordance with the methods described, or referred to, on pages ----- of these specifications, tests Nos. -----.

Methods of  
sampling and  
testing.

NOTE.—It is recommended that volumetric analyses be reported by the laboratory to facilitate field control.

#### SPECIFICATION FOR MINERAL FILLER.

The mineral filler shall consist of ----- (insert types allowable)  
It shall be free from foreign or other objectionable material and when tested by means of laboratory sieves shall meet the following requirements:

General.

Per cent.

Passing -----mesh sieve----- 100

Passing -----mesh sieve-----not less than -----

\* It is recommended that a 10-mesh sieve be specified.

† Ninety-five per cent is recommended for this purpose.

‡ It is recommended that 65 per cent be the minimum allowable strength ratio, and that in localities where practicable a higher strength ratio be specified.



**Methods of  
sampling and  
grading.**

The mineral filler shall be sampled for quality and grading in accordance with the method described on page -----, paragraph -----, of these specifications; and the grading shall be determined in accordance with the method described or referred to on page ----- of these specifications, test No. -----.

**SPECIFICATION FOR ROAD OILS FOR COLD APPLICATION.****General.  
Physical and  
chemical proper-  
ties.**

The road oil shall be homogeneous and free from water.

It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.), ----- to -----.
2. Flash point, not less than -----° C. (-----° F.).  
[or -----° C. (-----° F.) to -----° C. (-----° F.)\*]
3. Specific viscosity at -----° C.† (-----° F.), ----- to -----.
4. Loss at 163° C. (325° F.), 5 hours, not more than -----%,  
(or ----- to ----- per cent.)\*  
‡(a) Float test of residue at 50° C. (122° F.),  
----- to ----- sec.
5. Total bitumen (soluble in carbon disulphide) not less than  
----- per cent.
6. Per cent of total bitumen insoluble in 86° B. naphtha,  
----- to -----.

**Methods of  
testing.**

Tests of the physical and chemical properties of the road oil shall be made in accordance with the methods described or referred to on page ----- of these specifications, tests Nos. -----.

NOTES.—(1) In some instances it may be considered desirable to include a requirement for loss at 105° C. (221° F.), in which case the wording should be: Loss at 105° C. (221° F.), 5 hours, not less than ----- per cent.

(2) In some instances it may be considered desirable to include a requirement for the percentage of residue of ----- penetration, in which case the wording should be: Percentage of residue of ----- penetration, ----- to -----.

(3) In certain cases the inclusion of all the tests listed or noted may not be desirable, but it is necessary to use certain combinations of the tests in order to secure a material suitable for a specified purpose.

**SPECIFICATION FOR ROAD OILS FOR HOT APPLICATION.****General.  
Physical and  
chemical proper-  
ties.**

The road oil shall be homogeneous, free from water, and shall not foam when heated to -----° C. (-----° F.).

It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.), ----- to -----.

\*In cases where the presence of a volatile or light flux is desired the second form of the flash-point requirement and of the loss at 163° C. requirement should be used; in all other cases the first form of requirement is applicable.

† It is recommended that the viscosity determination be made at 25° C. (77° F.) or 40° C. (104° F.), according to the nature of the product desired.

‡ In case the oil is to be used as a dust layer only, this requirement is to be omitted.

2. Flash point, not less than \_\_\_\_\_° C. (\_\_\_\_\_° F.).  
[or \_\_\_\_\_° C. (\_\_\_\_\_° F.) to \_\_\_\_\_° C. (\_\_\_\_\_° F.).\*]
3. Specific viscosity at 100° C. (212° F.) \_\_\_\_\_ to \_\_\_\_\_
4. Float test at \_\_\_\_\_° C.† (\_\_\_\_\_° F.), \_\_\_\_\_ to \_\_\_\_\_ sec.
5. Loss at 163° C. (325° F.), 5 hours, not more than \_\_\_\_\_ per cent.

(or \_\_\_\_\_ to \_\_\_\_\_ per cent.\*)

(a) Float test of residue 50° C. (122° F.), \_\_\_\_\_ to \_\_\_\_\_ sec.

[or penetration of residue at 25° C. (77° F.), 100 g., 5 sec., \_\_\_\_\_ to \_\_\_\_\_.]

6. Total bitumen (soluble in carbon disulphide) not less than \_\_\_\_\_ per cent.

7. Per cent of total bitumen insoluble in 86° B. naphtha, \_\_\_\_\_ to \_\_\_\_\_

Tests of the physical and chemical properties of the road oil shall be made in accordance with the methods described or referred to on page \_\_\_\_\_ of these specifications, tests Nos. \_\_\_\_\_

**Methods of testing.**

NOTES.—(1) In some instances it may be considered desirable to include a requirement for the percentage of residue of \_\_\_\_\_ penetration, in which case the wording should be: Percentage of residue of \_\_\_\_\_ penetration, \_\_\_\_\_ to \_\_\_\_\_ per cent.

(2) In certain cases the inclusion of all the tests listed or noted may not be desirable, but it is necessary to use certain combinations of the tests in order to secure a material suitable for a specified purpose.

**SPECIFICATION FOR ASPHALT CEMENTS FOR USE IN BITUMINOUS MACADAM, BITUMINOUS CONCRETE AND SHEET ASPHALT, OR AS SEAL COAT OR POURED JOINT FILLER.**

The asphalt cement shall be homogeneous, free from water, and shall not foam when heated to \_\_\_\_\_° C. (\_\_\_\_\_° F.).

**General.**

It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.), \_\_\_\_\_ to \_\_\_\_\_.
2. Flash point, not less than \_\_\_\_\_° C. (\_\_\_\_\_° F.).
3. Melting point, \_\_\_\_\_° C. (\_\_\_\_\_° F.) to \_\_\_\_\_° C. (\_\_\_\_\_° F.).  
(or ductility at \_\_\_\_\_° C. (\_\_\_\_\_° F.), not less than \_\_\_\_\_ cm. (or \_\_\_\_\_ to \_\_\_\_\_ cm.))
4. Penetration at 25° C.‡ (77° F.), 100 g., 5 sec., \_\_\_\_\_ to \_\_\_\_\_.

**Physical and chemical properties.**

\* In cases where the presence of a volatile or light flux is desired, the second form of the flash-point requirement and of the loss at 163° C. requirement should be used; in all other cases the first form of requirement is applicable.

† It is recommended that the float test be made at 32° C. (90° F.) or 50° C. (122° F.), according to the nature of the product desired.

‡ In some instances it may be desirable to insert a requirement for penetration at the temperatures of 0° C. (32° F.) and 46.1° C. (115° F.) in which cases the clauses would read as follows: Penetration at 0° C. (32° F.), 200 g., 60 sec., \_\_\_\_\_ to \_\_\_\_\_, or not less than \_\_\_\_\_. Penetration at 46.1° C. (115° F.), 50 g., 5 sec., \_\_\_\_\_ to \_\_\_\_\_, [or not more than \_\_\_\_\_.]

5. Loss at 163° C. (325° F.), 5 hours, not more than ----- per cent.
  - (a) Penetration of residue at 25° C. (77° F.), 100 g., 5 sec., not less than -----.
6. Total bitumen (soluble in carbon disulphide) not less than ----- per cent.
  - (a) Organic matter insoluble, not more than ----- per cent.
  - (b) Inorganic matter insoluble, not more than ----- per cent.
  - (or ----- to ----- per cent).

Method of testing.

Tests of the physical and chemical properties of the asphalt cement shall be made in accordance with the methods described, or referred to on page ----- of these specifications, tests Nos. -----.

NOTES.—(1) In some instances it may be considered desirable to include an 86° B. naphtha solubility clause, in which case the wording should be: Per cent of total bitumen insoluble in 86° B. naphtha, ----- to ----- per cent.

(2) In some instances it may be considered desirable to include a fixed carbon requirement, in which case the wording should be: Fixed carbon, ----- to ----- per cent.

(3) In certain cases the inclusion of all the tests listed or noted may not be desirable, but it is necessary to use certain combinations of the tests in order to secure a material suitable for a specified purpose.

#### SPECIFICATION FOR TARS FOR COLD APPLICATION.

General.

The tar shall be homogeneous.

Physical and chemical properties.

It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.), ----- to -----.
2. Specific viscosity at -----° C.\* (-----° F.), ----- to -----.
3. Total distillate by weight:

Per cent.

To 170° C. (338° F.), not more than -----

To 235° C. (455° F.), not more than -----

To 270° C. (518° F.), not more than -----

To 300° C. (572° F.), not more than -----

(a) Melting point of residue -----° C. (-----° F.),  
to -----° C. (-----° F.).

4. Total bitumen (soluble in carbon disulphide, ----- to ----- per cent.

Methods of testing.

Tests of the physical and chemical properties of the tar shall be made in accordance with the methods described, or referred to, on page ----- of these specifications, tests Nos. -----.

NOTES.—(1) In some instances it may be desirable to insert a specific gravity of distillate requirement after the melting point requirement, in which case the wording should be: (b) Specific gravity of total distillate 25°/25° C. (77°/77° F.), ----- to -----.

(2) In some instances it may be considered desirable to insert a requirement for solubility in dimethyl sulphate of one or more fractions of the distillate. In such cases insert as follows: Solubility in dimethyl sulphate of distillate from -----° C. (-----° F.) to -----° C. (-----° F.), ----- to ----- per cent.

\* It is recommended that the viscosity determination be made at 25° C. (77° F.) or 40° C. (104° F.), according to the nature of the product desired.



**SPECIFICATION FOR REFINED TAR FOR USE IN BITUMINOUS MACADAM AND BITUMINOUS CONCRETE, OR AS SEAL COAT OR FOR HOT APPLICATION.**

The refined tar shall be homogeneous and free from water.

It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.), ----- to -----
2. Float test at -----° C.\* (-----° F.), ----- to ----- sec.
3. Total distillate by weight:

Per cent.

To 170° C. (338° F.), not more than -----

To 235° C. (455° F.), not more than -----

To 270° C. (518° F.), not more than -----

To 300° C. (572° F.), not more than -----

(a) Melting point of residue -----° C. (-----° F.), to  
-----° C. (-----° F.).

4. Total bitumen (soluble in carbon disulphide), ----- to  
----- per cent.

Tests of the physical and chemical properties of the refined tar shall be made in accordance with the methods described, or referred to, on page ----- of these specifications, tests Nos. -----

**General.**  
**Physical and chemical properties.**  
**Methods of testing.**

NOTES.—(1) In some instances it may be desirable to insert a specific gravity of distillate requirement after the melting point requirement, in which case the wording should be: (b) Specific gravity of total distillate, 25°/25° C. (77°/77° F.), ----- to -----

(2) In some instances it may be considered desirable to insert a requirement for solubility in dimethyl sulphate of one or more fractions of the distillate. In such cases insert as follows: Solubility in dimethyl sulphate of distillate, from -----° C. (-----° F.) to -----° C. (-----° F.), ----- to ----- per cent.

(3) In some instances it may be desirable to specify the specific viscosity of the material at the temperature applied. In such cases insert as follows: Specific viscosity, -----° C. (-----° F.), ----- to -----

**SPECIFICATION FOR REFINED TAR FOR USE AS POURED JOINT FILLER.**

The refined tar shall be homogeneous and free from water.

It shall meet the following requirements:

1. Specific gravity, 25°/25° C. (77°/77° F.), ----- to -----
2. Melting point, -----° C. (-----° F.) to -----° C. (-----° F.).
3. Total bitumen (soluble in carbon disulphide), ----- to  
----- per cent.

Tests of the physical and chemical properties of the refined tar shall be made in accordance with the methods described or referred to on page ----- of these specifications, tests Nos. -----

**General.**  
**Physical and chemical properties.**  
**Methods of testing.**

**SPECIFICATION FOR PORTLAND CEMENT.†**

(1) Portland cement is the product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions subsequent to calcination except water and calcined or uncalcined gypsum.

**Definition.**

\* It is recommended that the float test be made at 32° C. (89.6° F.) or 50° C. (122° F.), according to the nature of the product desired.

† Conforming with the report of a joint conference representing the United States Government, American Society of Civil Engineers, and the American Society for Testing Materials, published in Bureau of Standards Circular No. 33, 3d edition, and in the 1913 Standards of the American Society for Testing Materials, p. 429, etc., Serial Designation C9-17.

## I. CHEMICAL PROPERTIES.

Chemical  
limits.

(2) The following limits shall not be exceeded:

|                                             | Per cent. |
|---------------------------------------------|-----------|
| Loss on ignition.....                       | 4.00      |
| Insoluble residue.....                      | .85       |
| Sulphuric anhydride (SO <sub>3</sub> )..... | 2.00      |
| Magnesia (MgO).....                         | 5.00      |

## II. PHYSICAL PROPERTIES.

Specific grav-  
ity.

(3) The specific gravity of cement shall be not less than 3.10. Should the test of cement as received fall below this requirement, a second test may be made upon an ignited sample. The specific-gravity test will not be made unless specifically ordered.

## Fineness.

(4) The residue on a standard 200-mesh sieve shall not exceed 22 per cent by weight.\*

## Soundness.

(5) A pat of neat cement shall remain firm and hard, and show no signs of distortion, cracking, checking, or disintegration in the steam test for soundness.

Time of set-  
ting.

(6) The cement shall not develop initial set in less than 45 minutes when the Vicat needle is used, or 60 minutes when the Gillmore needle is used. Final set shall be attained within 10 hours.

Tensile  
strength.

(7) The average tensile strength in pounds per square inch of not less than three standard mortar briquets composed of 1 part cement and 3 parts standard sand, by weight, shall be equal to or higher than the following:

| Age at<br>test. | Storage of briquets.                      | Tensile<br>strength<br>per square<br>inch. |
|-----------------|-------------------------------------------|--------------------------------------------|
| <i>Days.</i>    |                                           | <i>Pounds.</i>                             |
| 7               | 1 day in moist air, 6 days in water.....  | 200                                        |
| 28              | 1 day in moist air, 27 days in water..... | 300                                        |

(8) The average tensile strength of standard mortar at 28 days shall be higher than the strength at 7 days.

## III. PACKAGES, MARKING, AND STORAGE.

Packages and  
marking.

(9) The cement shall be delivered in suitable bags or barrels with the brand and name of the manufacturer plainly marked thereon, unless shipped in bulk. A bag shall contain 94 pounds net. A barrel shall contain 376 pounds net.

## Storage.

(10) The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment, and in a suitable weather-tight building which will protect the cement from dampness.

\* The United States Government specification requires that on and after July 1, 1918, the residue on the 200-mesh sieve shall not exceed 20 per cent by weight.

## IV. INSPECTION.

(11) Every facility shall be provided the purchaser for careful sampling and inspection at either the mill or at the site of the work, as may be specified by the purchaser. At least 10 days from the time of sampling shall be allowed for the completion of the 7-day test; and at least 31 days shall be allowed for the completion of the 28-day test. The 28-day test shall be waived only when specifically ordered.\*

Inspection.

## V. REJECTION.

(12) The cement may be rejected if it fails to meet any of the requirements of these specifications.

Rejection.

(13) Cement shall not be rejected on account of failure to meet the fineness requirement if upon retest after drying at 100°C. (212° F.) for one hour it meets this requirement.

(14) Cement failing to meet the test for soundness in steam may be accepted if it passes a retest using a new sample at any time within 28 days thereafter.

(15) Packages varying more than 5 per cent from the specified weight may be rejected; and if the average weight of packages in any shipment, as shown by weighing 50 packages taken at random, is less than that specified, the entire shipment may be rejected.

The cement shall be sampled in accordance with the method described on page -----, paragraphs -----, of these specifications.

Method of sampling.

The cement shall be tested in accordance with the methods described, or referred to, on page ----- of these specifications, tests Nos. -----.

Methods of testing.

**SPECIFICATION FOR PORTLAND-CEMENT CONCRETE FOR WEARING SURFACE.  
(SUGGESTED CLAUSES FOR COMPOSITION AND CONSISTENCY.)**

The concrete shall be composed of 1 part of Portland cement and ----- parts of fine and coarse aggregate, measured separately and accurately by volume, and combined in such proportions as may be directed by the engineer, so as to give concrete of the greatest density and strength. The concrete shall be mixed in the approximate proportions of 1 part cement, ----- parts fine aggregate, and ----- parts coarse aggregate. In no case shall the parts of fine aggregate be less than -----† per cent nor more than -----‡ per cent of the total parts by volume of fine and coarse aggregate.

Composition.

The consistency of concrete should be such that when deposited it will settle in a flat mass, but will not flow on the subgrade. No tamping should be required, and no separation of the mortar from the coarse aggregate should occur in handling the concrete or in finishing the surface.

Consistency.

\* The conference recommends that in the application of this clause to working conditions the cement should not be held ordinarily pending the results of the 28-day test, but these tests nevertheless should be made invariably.

† The figure 30 is suggested.

‡ The figure 40 is suggested.



## SPECIFICATION FOR STEEL REINFORCING RODS.

|                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|-----------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>General.</b>                         | Rods shall be (insert form selected)* and (insert method of manufacture desired)† and shall conform to the following chemical and physical requirements. Twisted bars shall be twisted with one complete twist in a length not over 12 times the thickness of the bar.                                                                                                                                                                                                                                                                                              |
| <b>Chemical properties.</b>             | Rods shall meet the following chemical requirements:‡<br>Phosphorus—<br>Bessemer, not more than ----% per cent.<br>Open-hearth, not more than ----% per cent.                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Physical properties.</b>             | Rods shall meet the following requirements for physical properties:<br>Tension tests—<br>Tensile strength, not less than ----% pounds per square inch.<br>Yield point, not less than ----% pounds per square inch.<br>Elongation in 8 inches, not less than ----% per cent.<br>Cold bend test without cracking—<br>Thickness or diameter under $\frac{1}{4}$ inch, ----%°.<br>Thickness or diameter $\frac{1}{4}$ inch or more ----%°.                                                                                                                              |
| <b>Modifications in elongation.</b>     | For plain and deformed bars over three-quarters inch in thickness or diameter, a deduction of 1 from the percentages of elongation specified in the foregoing table shall be made for each increase of one-eighth inch in the thickness or diameter above three-fourths inch.<br>For plain and deformed bars under seven-sixteenths inch in thickness or diameter, a deduction of 1 from the percentages of elongation specified in the foregoing table shall be made for each decrease of one-sixteenth inch in thickness or diameter below seven-sixteenths inch. |
| <b>Weight.</b>                          | The weight of any lot of bars shall not vary more than 5 per cent from the theoretical weight of that lot.                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Storage.</b>                         | Steel rods shall be so stored as to prevent the formation of rust scales and when used on the work they shall be free from dust, dirt, loose rust, paint, oil, or grease.                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Methods of sampling and testing.</b> | Rods shall be sampled in accordance with the methods described on page -----, paragraphs -----, of these specifications, and tested in accordance with the methods described or referred to on pages ----- of these specifications, tests Nos. -----.                                                                                                                                                                                                                                                                                                               |

## SPECIFICATION FOR VITRIFIED PAVING BRICK.

|                 |                                                                                                                                                                                                                                                         |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>General.</b> | All brick shall be of a size commercially known as "vitrified block." They shall be thoroughly annealed, tough and durable, regular in size and shape and evenly burned. When broken the bricks shall show a dense, stonelike body, free from lime, air |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

\* Plain, deformed, hot or cold twisted, as may be desired.

† Rolled from new billets made by Bessemer or open-hearth process or rolled from standard section tee rails, as may be specified.

‡ To be applied only to rods rolled from billets.

§ The values given in American Society for Testing Materials Standards, 1916, serial designation A15-14, for the particular kind of material desired, are recommended for insertion in this table.

pockets, cracks, or marked laminations. Kiln marks shall not exceed ----- of an inch, and the wearing surface shall show but slight kiln marks.

Representative samples of the brick shall meet the following requirements when subjected to the rattler test:

**Rattler test.**

Average loss by abrasion on one or more tests, not more than ----- per cent.

Maximum difference in per cent loss by abrasion when more than one representative sample is tested, not more than -----per cent.

A maximum of three tests will be used as a basis for rejection.

The bricks shall meet the following requirements:

**Dimensions.**

Length ----- to ----- inches.

Width, ----- to ----- inches.

Depth, ----- to ----- inches.

Variations among bricks from a single plant shall not exceed the following limits:

Variation in length, ----- inch.

Variation in width, ----- inch.

Variation in depth, ----- inch.

If the edges of the bricks are rounded, the radius shall not exceed ----- of an inch.

Only bricks with lugs on one side, raised not less than ----- of an inch, nor more than ----- of an inch, shall be used.

The bricks shall be subjected to inspection subsequent to delivery at the place of use, prior to and during laying, in order to cull out and reject upon variations from the general and dimensions clauses and upon the following grounds:

**Visual inspection.**

All bricks which are broken through, or chipped in such manner that neither wearing surface remains substantially intact, or in such manner that the lower or bearing surface is reduced in area by more than one-fifth.

All bricks which are cracked to a depth greater than -----inch on any surface, or which are cracked on the wearing surface.

All bricks which are so off-size or so misshaped, bent, twisted, or kiln-marked that they will not form a proper surface or align properly with other bricks.

All bricks which are obviously too soft and too poorly vitrified to endure street wear.

Bricks shall be sampled in accordance with the method described on page ----- of these specifications, and tested in accordance with the method described or referred to on page ----- of these specifications, test No. -----.

**Methods of sampling and testing.**

**NOTE.**—The committee does not recommend an absorption test for general use in specifications. If special conditions make such a test necessary, it may be specified.

## RECOMMENDED STANDARD METHODS OF TESTING MATERIALS.

TESTS OF PHYSICAL PROPERTIES OF STONE, SLAG, GRAVEL,  
AND SAND.

(1) ABRASION TEST (PER CENT OF WEAR, OR FRENCH COEFFICIENT OF WEAR), STONE, STONE BLOCK, AND SLAG: United States Department of Agriculture Bulletin 347, page 5.

NOTES.—(a) Attention is directed to the fact that tests of rock and slag for abrasion by the use of the Deval machine are not entirely satisfactory. The formation of a dust cushion in the cylinder partially prevents the abrasion of the stone. Sufficient data are not at hand to show the amount of wear when this dust cushion is removed after intervals of time.

(b) It is hoped that laboratories will take up this test with the idea of developing a coefficient of wear more nearly representative of the actual resistance of the stone.

(c) It is desired to call attention to the fact that two methods of preparing the stone or slag are in use—viz, hand breaking and machine breaking, and furthermore to recommend that arrangements be made between States for conducting check tests for abrasion on portions of the same sample.

(d) In testing light stone and light slag, it is recommended that some standard volume be substituted for the standard weight of 5,000 grams.

(e) In the case of stone block it is recommended that the laboratories co-operate to devise new methods of testing stone block to determine their suitability for pavements.

## (2) ABRASION TEST, SUGGESTED FOR GRAVEL:

The aggregate is screened first through screens having circular openings 2 inches, 1 inch, and  $\frac{1}{2}$  inch in diameter. The sizes used for this test are divided equally between those passing the 2-inch and retained on the 1-inch screen, and those passing the 1-inch and retained on the  $\frac{1}{2}$ -inch screen. The material of these sizes is washed and dried. The following weights of the dried stone are then taken: 2,500 grams of the size passing the 2-inch and retained on the 1-inch screen, and 2,500 grams of the size passing the 1-inch and retained on the  $\frac{1}{2}$ -inch screen. This material is placed in the cast-iron cylinder of the Deval machine as specified for the standard abrasion test on stone. Briefly described, this machine consists of a frame and two or more cylinders mounted at an angle of  $30^\circ$  with the axis of rotation. The cylinders are of the following size: 20 cm. diameter by 34 cm. deep, inside dimensions. Six cast-iron spheres 1.875 inches in diameter and weighing approximately 0.95 pound (0.45 kg.) each, are placed in the cylinder as an abrasive charge. The iron composing these spheres, which are the same as those used in the standard paving brick rattler test, has the following limits of composition:

Combined carbon, not under 2.50 per cent.

Graphitic carbon, not over 0.25 per cent.

Silicon, not over 1.00 per cent.

Manganese, not over 0.50 per cent.

Phosphorus, not over 0.25 per cent.

Sulphur, not over 0.08 per cent.

After the cast-iron spheres have been placed in the cylinder the lid is bolted on and the cylinder mounted in the frame of the Deval machine. The duration of the test and the rate of rotation are the same as specified for the standard test for stone, namely, 10,000 revolutions at a rate of 30 to 33 revolutions per minute. At the completion of the test the material is taken out and screened through a 16 mesh sieve. The material retained upon the sieve is washed and dried and the per cent loss by abrasion of the material passing the 16 mesh sieve calculated.



When the material has a specific gravity below 2.20 a total weight of 4,000 grams instead of 5,000 grams shall be used in the abrasion test.

(3) TOUGHNESS TEST, STONE: United States Department of Agriculture Bulletin 347, page 15.

(4) HARDNESS TEST,<sup>1</sup> STONE AND STONE BLOCK: United States Department of Agriculture Bulletin 347, page 10.

(5) SPECIFIC GRAVITY AND ABSORPTION TESTS, STONE:

The apparent specific gravity is obtained by weighing the water displaced by a sample of the material weighing approximately 1,000 grams, broken into pieces about  $1\frac{1}{4}$  inches in diameter. (The vessel used is shown in figure 1.)

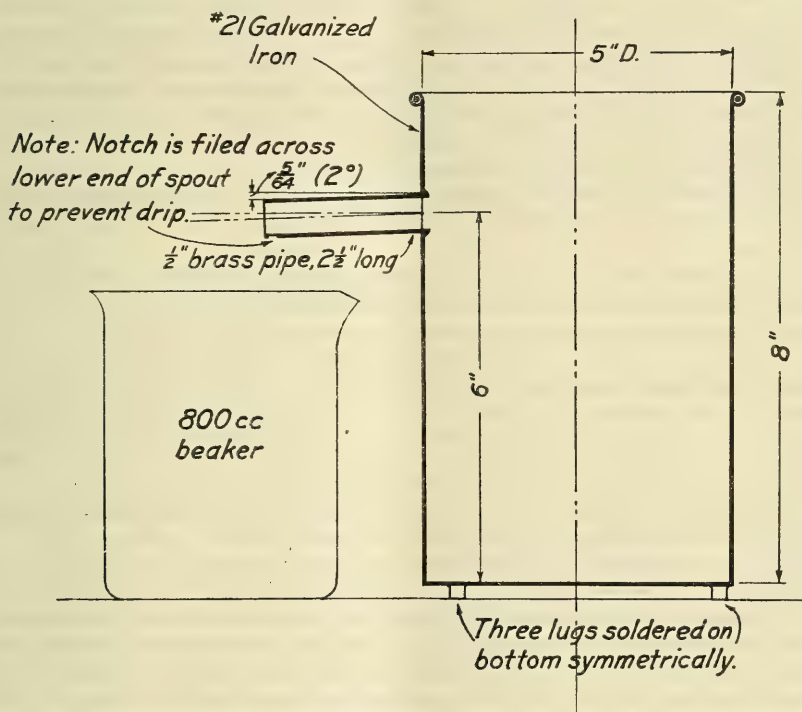


FIG. 1.—Vessel used in making specific-gravity and absorption tests.

It consists of a galvanized-iron cylinder closed at one end, and measuring 5 inches in diameter by 8 inches high. A brass spout  $\frac{1}{2}$  inch in diameter is soldered into the side of the cylinder, 6 inches from the bottom. The spout is inclined at an angle of  $2^\circ$  with the horizontal and is  $2\frac{1}{2}$  inches long. A notch is filed across its lower end, as shown, to stop the drip from the displaced water. In determining the specific gravity, the dried and cooled sample is weighed to the nearest 0.5 gram and immersed in water for 24 hours. The pieces are then individually surface-dried with a towel, the sample reweighed, and immediately placed in the cylinder, which has been previously filled to overflowing with water at room temperature.

The weight of water displaced by the sample is used to calculate its apparent specific gravity.

<sup>1</sup> It is recommended that the laboratories cooperate with the view of devising an improved method for the determination of the hardness of rock, especially in regard to the character of the abrasive used.

The difference between the original weight of the sample and its weight after 24 hours immersion is used to determine the absorption.

(6) WEIGHT PER CUBIC FOOT TEST, SLAG:

The dried slag shall be shaken to refusal in a cubic-foot measure or other suitable container, and its weight determined.

(7) MORTAR-STRENGTH TEST, SCREENINGS AND SAND: A. S. T. M. Standard test C9-17.

SIZE, GRADING, OR MECHANICAL ANALYSIS OF STONE, SLAG, GRAVEL, SAND.

(8) TEST OF SIZE OR GRADING OF COARSE AGGREGATE, STONE, SLAG, AND GRAVEL:

A sample of the material weighing not less than fifty (50) times the weight of the largest size stone present is to be used. After drying at not over 110°C. (230°F.) to constant weight the sample is passed through such of the following size screens, having circular openings, as are required or called for by the specifications, screens to be used in the order named: 3½-inch, 3-inch, 2½-inch, 2-inch, 1½-inch, 1-inch, ¾-inch, ½-inch, and ¼-inch.

The percentage by weight, retained on each screen, is determined and the mechanical analysis is recorded in the following manner:

|                                                           | Per cent. |
|-----------------------------------------------------------|-----------|
| Passing 3½-inch screen and retained on 3-inch screen----- | ---       |
| Passing 3-inch screen and retained on 2½-inch screen----- | ---       |
| Passing 2½-inch screen and retained on 2-inch screen----- | ---       |
| -----                                                     | ---       |
| Passing ½-inch screen and retained on ¼-inch screen-----  | ---       |
| Passing ¼-inch screen-----                                | ---       |
|                                                           | 100       |

(9) WASHING TEST AND MECHANICAL ANALYSIS, ROAD GRAVEL:

A sample of the material weighing not less than 50 times the weight of the largest size stone present is to be used. After thoroughly drying at 100° C. (212° F.) in a hot-air bath, the sample is cooled, weighed, and placed in a shallow pan, covered with water, and thoroughly agitated by means of a trowel for 15 seconds. After 15 seconds sedimentation the water is poured off through a 200-mesh sieve, and the operation of agitation, sedimentation, and decantation repeated until the wash water is approximately clear after 15 seconds. The washed material, together with any residue retained on the 200-mesh sieve, is then dried to constant weight, cooled and weighed and passed through such of the following size screens and sieves as are called for in the specification, using them in the order named.

*Screens* (circular openings): 3-inch, 2½-inch, 2-inch, 1½-inch, 1-inch, ¾-inch, ½-inch, and ¼-inch.

*Sieves* A. S. T. M. standard method D7-16 (square mesh): 10, 20, 30, 40, 50, 60, 80, 100, and 200 meshes per linear inch.

The percentage by weight retained on each screen or sieve and based on the weight of the original sample is calculated, using for the determination of the percentage of material passing the 200-mesh sieve the sum of the weights of material passing this sieve by analysis and by washing.

(10) ELUTRIATION TEST, SAND OR FINE AGGREGATE:

The entire sample is moistened and thoroughly mixed, and a sample weighing approximately 105<sup>1</sup> grams is obtained for elutriation and grading by quartering or by selecting small portions from various parts of a flat pile. The sample is then dried at not over 110° C. (230° F.). This dried sample is accurately weighted and placed in a 500-cc.<sup>1</sup> beaker, and about 350 cc.<sup>1</sup> of

water is added and agitated in such manner that no whirling results. After settling for 20 seconds the water is poured off through a 200-mesh sieve, and the operation of agitation, sedimentation, and decantation repeated until the wash water is approximately clear. Particles caught on the 200-mesh sieve are then washed back into the washed sample remaining in the beaker. The entire washed sample is dried to constant weight and accurately weighed, and the

$$\text{Per cent by elutriation} = \frac{\text{Original weight} - \text{final weight}}{\text{Original weight}}$$

(11) MECHANICAL ANALYSIS, SAND OR FINE AGGREGATE:

All of the dried sample remaining after the elutriation test, if such is required, is passed successively through the desired screens and sieves, beginning with either the largest or smallest as may be convenient. Where an elutriation test is not required, a dried sample of the original material is used.

The percentage by weight, of the unwashed sample retained on each screen is determined, and the mechanical analysis is recorded according to one or both of the following methods. A screen with  $\frac{1}{4}$ -inch circular openings is used, together with square-mesh sieves as specified in A. S. T. M. standard method D7-16.

|                                                                  | Per cent. |
|------------------------------------------------------------------|-----------|
| Total retained on $\frac{1}{4}$ -inch screen                     | -----     |
| Passing $\frac{1}{4}$ -inch screen and retained on 10-mesh sieve | -----     |
| Passing 10-mesh sieve and retained on 20-mesh sieve              | -----     |
| Passing 20-mesh sieve and retained on 30-mesh sieve              | -----     |
| Passing 30-mesh sieve and retained on 40-mesh sieve              | -----     |
| Passing 40-mesh sieve and retained on 50-mesh sieve              | -----     |
| Passing 50-mesh sieve and retained on 80-mesh sieve              | -----     |
| Passing 80-mesh sieve and retained on 100-mesh sieve             | -----     |
| Passing 100-mesh sieve and retained on 200-mesh sieve            | -----     |
| Passing 200-mesh sieve                                           | -----     |
| Total                                                            | ----- 100 |

|                                          | Per cent. |
|------------------------------------------|-----------|
| Total passing $\frac{1}{4}$ -inch screen | -----     |
| Total passing 10-mesh sieve              | -----     |
| Total passing 20-mesh sieve              | -----     |
| Total passing 30-mesh sieve              | -----     |
| Total passing 40-mesh sieve              | -----     |
| Total passing 50-mesh sieve              | -----     |
| Total passing 80-mesh sieve              | -----     |
| Total passing 100-mesh sieve             | -----     |
| Total passing 200-mesh sieve             | -----     |
| Passing 200-mesh sieve elutriation       | -----     |

MECHANICAL ANALYSIS AND TESTS OF PHYSICAL PROPERTIES OF SEMI-GRAVEL, TOP-SOIL, AND SAND-CLAY AGGREGATES.

INTRODUCTION BY THE COMMITTEE.

The committee has been charged with consideration of that large range of natural soils and aggregates which lie below the usual classification of gravel, and which in the past 10 years have commended themselves to low-cost road

<sup>1</sup> If the sand is so coarse that a 100-gram sample is not sufficient, the size of the sample, the container, and the amount of water used may be proportionally increased.



surfacing in various sections of the country. The terms sand-clay roads, top-soil roads, and semi-gravel roads have come into road literature as designating various types of construction that utilize either natural surface soil, or subsurface deposits, or artificial mixtures wherein the chief ingredients are siliceous sands and natural clays. The abundant distribution of these two soil ingredients either separately in deposits or already mixed in many soils and substrata, has attracted attention and experiment to an extent which now justifies some attempt at classification and more definite statement of specifications and methods upon which satisfactory results may be predicated.

The better known and more expensive road surfacing materials have had the benefit of long study and detailed specification as a basis for control of contract work. But much of the large mileage of the types herein considered has been constructed by force account and with comparatively recent study of the proper bases and considerations out of which systematic specifications and methods could be formulated. The prospect of Federal-aid contracts in various States makes it very desirable that some such standardization should now be attempted as a guide to expenditures in those States where such types of construction either now prevail or where conditions indicate their desirability and efficiency in connection with possible Federal-aid projects.

The present state of knowledge regarding these materials is derived from the comparative study of the road history under traffic of such roads and the mechanical analyses of the constituent materials. The data secured indicate the necessity of classification and tests based upon a more complete separation of the ingredients than is usually given in a laboratory analysis. Special definitions of the terms "sand," "silt," and "clay" are required, also a theory of their mutual interaction after consolidation. It is believed that the adhesive clay, acting as a binder in dry weather and as a stopper to capillary openings by swelling in wet weather, must be supplemented by the interlocking strength of the sand aggregate both in dry and in wet weather to support the weight and the wear of the traffic, while the nonadhesive silt gives aid to density and water resistance. The proportions and sizes of the sand content are highly important for the strength and wearing element. The clay, owing to its expansion under wet conditions, should be present in minimum amount consistent with sufficient adhesion in dry weather, and the silt should form the inert filler for those voids not occupied by the clay.

The thorough intermixing of the ingredients is a vital factor and a process of consolidation which will pack the loose mass from the bottom upward is of much consequence.

A further conception of the action of this class of materials suggests that the fine aggregate passing a 10-mesh sieve may be regarded as a mortar capable of being used separately to form the road slab or of carrying any amount of gravel or coarse aggregate up to the point where a complete gravel road is reached with this mortar as its binder. Experience has shown that the addition of coarse material retained on a 10-mesh sieve and less than 2 inches in size, provided the coarse material is itself present in graded sizes, increases the durability of these soil mixtures. Further, the analysis of the fine material passing a 10-mesh sieve in the well-known Augusta (Ga.) gravel, which possesses excellent binding value, reveals a composition similar to some of the best top-soil roads in that State. There is reason to think that the binders in washed gravel roads might very well be compounded on the same basis as successful soil road mixtures.

The successful use of these road soil mixtures, whether obtained on the surface, as top soils, from substrata, or from artificial mixtures of clay and sand, depends primarily on the composition as to size, amount, quality, and

uniformity of mixing of the three usual ingredients and upon the adequate consolidation of the mass. From the practical standpoint the selection of the raw material should not be based on a too narrow analytic figure. The natural deposits are of variable composition. A number of samples from a selected area close to the work may not conform to a specific percentage, but it is usually possible to supplement deficiencies by adding relatively small quantities of sand or clay, as the case may be, and secure in the mixed roadbed a fairly uniform material whose analysis is satisfactory.

The final acceptance of a material of this class should preferably be based on samples taken at specified intervals on the freshly laid and intermixed roadbed and at such other points as the inspector may choose where the indications are that the mixture is not uniform and satisfactory.

In the light of the above brief statement the specifications, methods of test, methods of sampling, and form of reporting test results on these materials will be more readily understood.

#### (12) EXAMINATION SEMI-GRAVEL, TOP-SOIL, AND SAND-CLAY:

Dry 500 grams of the material at a temperature below 350° F. (176.6° C.) to constant weight. Gently pulverize to break down soft clods or masses, but not to grind or break hard material. Pass through a 10-mesh sieve, weigh the coarse residue and record as "coarse material." Use the material passing the 10-mesh sieve as the starting point of a percentage analysis as follows:

Weigh out two samples of 50 grams of this material for duplicate analysis. Place each in a wide mouth bottle (5 to 6 cm. diameter and about 12 to 15 cm. high). Add about 5 c. c. of dilute ammonia water and about 200 c. c. of water. Close with a cork or glass stopper and shake thoroughly for 20 minutes. Allow the sample to settle eight minutes and decant carefully or siphon off the supernatant liquid to a depth of 8 cm. below the surface of the liquid. (The depth of the liquid in the bottle should be sufficient to leave about 4 cm. below the point of siphoning.) Fill the bottle again with water, shake for three minutes, allow settlement, and siphon off as before. Repeat the process until the supernatant liquid is clear. Be careful to wash the stopper and neck of the bottle free from coarse material before decanting. The washings drawn off may be collected and evaporated to dryness for direct recovery of the fine sediment classed as "clay." Ordinarily the sediment loss or clay is computed as difference.

Wash the contents of the bottle cleanly into a porcelain evaporating dish and carry to dryness on a water bath. The dried residue should be carefully scraped from the dish and passed through a nest of 20, 60, 100, and 200 mesh sieves. The residue retained on each sieve is weighed and recorded as sand of the respective sizes. Their sum constitutes the total "sand." The residue passing the 200-mesh sieve and caught in the pan is weighed and recorded as "silt." Duplicate samples should check within 1 per cent.

(a) The coarse material should be examined for hardness and with the magnifying glass to identify its character as quartz, hard iron compounds, feldspar, schistose material, or indurated clay. Hard quartz or iron gravels are valuable in themselves and as indicating the quality of the finer aggregate. Feldspar, mica, and clay nodules are worthless and indicate that the accompanying soil is poor for road building.

(b) The sands should be examined with the magnifying glass for identification as quartz and for the presence of mica scales or feldspar needles. If mica or feldspar is present in appreciable amounts the sample should be rejected.

(c) When the clay is recovered by evaporation it can be examined for tenacity by cementing together two glass plates, each 1 inch wide, set at right angles, with a layer of clay whose thickness is fixed by a fine bent wire laid between

the plates. The moist clay covers the wire on one plate, and the other plate is squeezed down tightly on the wire. After drying, the one plate being held firmly against cleats, wire slings are run symmetrically from the ends of the upper plate to one arm of a beam balance, and the tension necessary to separate the plates is given by shot or weights in the other pan of the balance. This test is tedious and is of service chiefly on low-grade samples which are of doubtful efficiency, but which represent the only available material for local construction.

(d) Approximate tests for tenacity of mixture can be made as follows:

Make cylinders from the material passing the 10-mesh sieve, 25 mm. by 25 mm. The material is worked into a stiff mud and molded under 132 kg. per sq. cm. pressure. Dry thoroughly at 100° C. (212° F.) and break by the small Page impact machine for testing cementing value, using a 1 kg. hammer and 1 cm. drop. Record the number of strokes as the relative measure of tenacity.

Mix 50 grams of the material passing the 10-mesh sieve with ——— grams of water and knead with the hands into a spherical ball. Measure the diameter. Let this ball drop from a height of ——— cm. on a flat slab. Measure and record the reduction in diameter and examine the surface for cracks.

Usually the plastic character and adhesiveness of a good road soil can be judged by the feeling of the mud made from this material, its adherence to the hands, and its stretch under light pulling.

#### TESTS OF PHYSICAL AND CHEMICAL PROPERTIES OF BITUMINOUS MATERIALS.

(13) SPECIFIC GRAVITY: Standardized hydrometers or pycnometers. U. S. Department of Agriculture Bulletin 314, pp. 4 to 7.

(14) FLASH POINT (OPEN CUP): U. S. Department of Agriculture Bulletin 314, p. 17.

(15) MELTING POINT: A. S. T. M. tentative standard D36-16T; Proc. A. S. T. M. 1916, p. 549.

(16) DUCTILITY: A. S. C. E. 1914 Proceedings, p. 3047.

(17) PENETRATION: A. S. T. M. standard test D5-16.

(18) FLOAT TEST: U. S. Department of Agriculture Bulletin 314, p. 9.

(19) SPECIFIC VISCOSITY (ON FIRST 50 C.C.): U. S. Department of Agriculture Bulletin 314, p. 7.

(20) TOTAL BITUMEN AND ORGANIC AND INORGANIC MATTER INSOLUBLE IN CARBON DISULPHIDE: U. S. Department of Agriculture Bulletin 314, p. 25.

(21) BITUMEN INSOLUBLE IN NAPHTHA: U. S. Department of Agriculture Bulletin 314, p. 28.

(22) VOLATILIZATION TEST (LOSS AT 163° C. OR OTHER TEMPERATURE): U. S. Department of Agriculture Bulletin 314, p. 19, except that a 50-gram sample is used in a flat-bottom box 55 mm. diameter by 35 mm. deep (Gill style, 3-ounce deep pattern box).

(23) DISTILLATION TEST: A. S. T. M. standard test D20-16.

(24) FIXED CARBON: U. S. Department of Agriculture Bulletin 314, p. 30.

(25) DIMETHYL SULPHATE TEST: U. S. Department of Agriculture Bulletin 314, p. 25.

(26) PERCENTAGE OF RESIDUE OF ——— PENETRATION:

Fifty grams of the oil are placed in a 3-ounce deep, seamless tin box; the box is placed in a sand bath and heated over a Bunsen burner. A thermometer is suspended in the oil, the bulb not touching the bottom of the box. The temperature of the oil is kept at from 249° C. (480° F.) to 260° C. (500° F.), and the oil is stirred from time to time with the thermometer to prevent over-



heating in any part. Depending upon the nature of the oil, as usually indicated by its flash, consistency at 25° C. (77° F.), and specific gravity, the operator can with experience tell about what percentage it will be necessary to evaporate before cooling and taking a penetration of the residue. It is sometimes necessary to make several trials before the desired result is obtained. When the required penetration is reached the residue left from evaporation is weighed and its per cent of the original sample taken is computed.

## TESTS OF PORTLAND CEMENT, PORTLAND CEMENT CONCRETE, STEEL REINFORCING RODS, AND VITRIFIED PAVING BRICK.

### (27) TESTS OF PORTLAND CEMENT:

- (a) Chemical analysis, A. S. T. M. standard test C 9-17.
- (b) Specific gravity, A. S. T. M. standard test C 9-17.
- (c) Fineness, A. S. T. M. standard test C 9-17.
- (d) Soundness, A. S. T. M. standard test C 9-17.
- (e) Time of setting, A. S. T. M. standard test C 9-17.
- (f) Tensile strength, A. S. T. M. standard test C 9-17.

### (28) TESTS OF FIELD SAMPLES OF PORTLAND CEMENT CONCRETE:

*Form of specimen.*—The test specimen may be a cube, a prism, or a cylinder, but it is felt that a cylinder six (6) inches in diameter by twelve (12) inches high will give the most satisfactory results. Molds of all types can be successfully used, from the most permanent to those which can be used only in forming a single specimen.

*Molding specimens.*—The molding should be done as near the mixer as practicable, and the concrete should be conveyed to the molds with as little jarring or mixing as possible. The molds should be placed on a flat, nonabsorbent surface, and the concrete should be placed in layers of ----- inches, with slight puddling by means of a half-inch steel rod.

*Storing.*—Specimens should be permitted to remain in position where molded for a period of 24 hours. At the end of that period they may be stored on the completed concrete pavement, buried in the same covering material, and moistened at the same intervals, until ready for shipment to the laboratory; or, if not considered practicable to store on the completed concrete, they may be covered at the point of molding with the same covering material as used for the concrete pavement and moistened at the same intervals, until shipped to the laboratory.

*Shipment.*—Specimens must be suitably protected from injury during shipment.

*Testing.*—Specimens should be capped with mortar shortly after molding, or with plaster of Paris just before testing, so as to provide plane bearing surfaces. The plane surface is formed by placing the specimen on a flat, non-absorbent surface and pressing a flat plate on the soft mortar or plaster cap. In testing, the specimens are mounted in the testing machine with spherical bearing block placed on top of the specimen, the capped specimen being placed in direct contact with the steel bearing surfaces.

(29) TESTS OF STEEL REINFORCING RODS: As given in the standard specifications for reinforcement bars, A. S. T. M. standard, 1916, serial designations A 15-14 and A 16-14.

(30) RATTLER TESTS, VITRIFIED PAVING BRICK: A. S. T. M. standard specification C 7-15.

NOTE.—All of the American Society for Testing Materials Methods, Tests, or Specifications above referred to will be found in the A. S. T. M. Standards, 1916, unless otherwise noted.

RECOMMENDED STANDARD FORMS FOR REPORTING TEST RESULTS.<sup>1</sup>

(Name and location of laboratory:)  
-----  
-----

REPORT ON SAMPLE OF ROCK OR SLAG.

Laboratory No. -----

-----, 191\_\_\_\_  
(Date reported.)

Name -----  
Identification marks -----  
Submitted by ----- Title ----- Address -----  
Sampled -----, 191\_\_\_\_ Received -----, 191\_\_\_\_  
Sampled from -----  
Quantity represented -----  
Source of material -----  
Location used or to be used -----  
Examined for -----

TEST RESULTS.

Specific gravity -----  
Weight per cubic foot, in pounds -----  
Water absorbed per cubic foot, ----- pounds ----- per cent  
Per cent of wear -----  
French coefficient of wear -----  
Hardness -----  
Toughness -----

Remarks:

Respectfully submitted.

(Title) -----

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<sup>1</sup>The arrangement of the test results on the report for gravel or sand, as reported by the conference, has been altered slightly so that the report might be made on a single sheet. In the case of petroleum and asphalt products and tars, the tests to be reported upon were definitely recommended by the conference, but no specific recommendation was made as to the order of arranging the various test results on the report form. The form, as presented, has been arranged in editing.

(Name and location of laboratory:)

## REPORT ON SAMPLE OF GRAVEL OR SAND.

Laboratory No. \_\_\_\_\_

\_\_\_\_\_, 191\_\_.

(Date reported.)

Name \_\_\_\_\_

Identification marks \_\_\_\_\_

Submitted by \_\_\_\_\_

Title \_\_\_\_\_

Address \_\_\_\_\_

Sampled \_\_\_\_\_

191\_\_

Received \_\_\_\_\_

191\_\_

Sampled from \_\_\_\_\_

Quantity represented \_\_\_\_\_

Source of material \_\_\_\_\_

Location used or to be used \_\_\_\_\_

Examined for \_\_\_\_\_

## TEST RESULTS.

| SAND.                                             |           | GRAVEL.                                                      |           |
|---------------------------------------------------|-----------|--------------------------------------------------------------|-----------|
| Mechanical analysis.                              |           | Mechanical analysis.                                         |           |
| Fraction.                                         | Per cent. | Fraction.                                                    | Per cent. |
| Retained $\frac{1}{8}$ -inch screen.....          | .....     | Retained 3-inch screen.....                                  | .....     |
| Passing $\frac{1}{8}$ -inch retained 10 mesh..... | .....     | Passing 3-inch retained $2\frac{1}{2}$ inch.....             | .....     |
| Passing 10 mesh retained 20 mesh.....             | .....     | Passing $2\frac{1}{2}$ -inch retained 2 inch.....            | .....     |
| Passing 20 mesh retained 30 mesh.....             | .....     | Passing 2-inch retained $1\frac{1}{2}$ inch.....             | .....     |
| Passing 30 mesh retained 40 mesh.....             | .....     | Passing $1\frac{1}{2}$ -inch retained 1 inch.....            | .....     |
| Passing 40 mesh retained 50 mesh.....             | .....     | Passing 1-inch retained $\frac{3}{4}$ inch.....              | .....     |
| Passing 50 mesh retained 60 mesh.....             | .....     | Passing $\frac{3}{4}$ -inch retained $\frac{1}{2}$ inch..... | .....     |
| Passing 60 mesh retained 80 mesh.....             | .....     | Passing $\frac{1}{2}$ -inch retained $\frac{1}{4}$ inch..... | .....     |
| Passing 80 mesh retained 100 mesh.....            | .....     | Passing $\frac{1}{4}$ -inch screen.....                      | .....     |
| Passing 100 mesh retained 200 mesh.....           | .....     |                                                              |           |
| Passing 200 mesh.....                             | .....     |                                                              |           |
| Total.....                                        | .....     | Total.....                                                   | .....     |
| Silt in sand.....                                 | .....     | Per cent of wear.....                                        | .....     |

| Tensile strength (cement-sand<br>briquettes, 1:3). | Sample sand. |        |         | Standard Ottawa sand. |        |         |
|----------------------------------------------------|--------------|--------|---------|-----------------------|--------|---------|
|                                                    | 3-day.       | 7-day. | 28-day. | 3-day.                | 7-day. | 28-day. |
| 1.....                                             | .....        | .....  | .....   | .....                 | .....  | .....   |
| 2.....                                             | .....        | .....  | .....   | .....                 | .....  | .....   |
| 3.....                                             | .....        | .....  | .....   | .....                 | .....  | .....   |
| 4.....                                             | .....        | .....  | .....   | .....                 | .....  | .....   |
| 5.....                                             | .....        | .....  | .....   | .....                 | .....  | .....   |
| Average.....                                       | .....        | .....  | .....   | .....                 | .....  | .....   |
| Ratio.....                                         | .....        | .....  | .....   | .....                 | .....  | .....   |

Remarks:

Respectfully submitted,

(Title) \_\_\_\_\_



(Name and location of laboratory :)

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## REPORT ON SAMPLE OF SEMI-GRAVEL, TOP SOIL, OR SAND CLAY.

Laboratory No. -----, 191--  
(Date reported.)Name -----  
Identification marks -----  
Submitted by ----- Title ----- Address -----  
Sampled -----, 191-- Received -----, 191--  
Sampled from -----  
Quantity represented -----  
Source of material -----  
Location used or to be used -----  
Examined for -----

## TEST RESULTS.

*Analysis of material passing 10-mesh sieve.*

|                                      | Per cent. | Per cent. | Per cent. | Character. |
|--------------------------------------|-----------|-----------|-----------|------------|
| Sand retained, 20 mesh .....         | .....     | .....     | .....     |            |
| Passing 20, retained 60 mesh .....   | .....     | .....     | .....     |            |
| Passing 60, retained 100 mesh .....  | .....     | .....     | .....     |            |
| Passing 100, retained 200 mesh ..... | .....     | .....     | .....     |            |
| Total sand .....                     | .....     | .....     | .....     |            |
| Silt .....                           | .....     | .....     | .....     |            |
| Clay .....                           | .....     | .....     | .....     |            |
| Total .....                          | .....     | .....     | .....     |            |
| Total sand retained on 60 mesh ..    | .....     | .....     | .....     |            |
|                                      | .....     | .....     | .....     |            |

Coarse material, ----- per cent. Quality, -----

Mica, -----

Remarks:

Respectfully submitted,

-----  
(Title) -----

(Name and location of laboratory:)

REPORT ON SAMPLE OF PETROLEUM OR ASPHALT PRODUCTS.

(Classification name of material.)

Laboratory No. \_\_\_\_\_ (Date reported.) \_\_\_\_\_, 191\_\_  
 Trade name \_\_\_\_\_  
 Identification marks \_\_\_\_\_  
 Submitted by \_\_\_\_\_ Title \_\_\_\_\_ Address \_\_\_\_\_  
 Sampled \_\_\_\_\_, 191\_\_ Received \_\_\_\_\_, 191\_\_  
 Sampled from \_\_\_\_\_  
 Quantity represented \_\_\_\_\_  
 Manufactured by \_\_\_\_\_  
 Location used or to be used \_\_\_\_\_  
 Examined for \_\_\_\_\_

TEST RESULTS.

General characteristics \_\_\_\_\_  
 Specific gravity, 25° C./25° C. \_\_\_\_\_  
 Flash point (° C.) \_\_\_\_\_  
 Specific viscosity, Engler at \_\_\_\_\_° C. \_\_\_\_\_  
 Float test, \_\_\_\_\_° C., (seconds) \_\_\_\_\_; \_\_\_\_\_° C., (seconds) \_\_\_\_\_  
 Penetration, 25° C., 100 grams, 5 seconds \_\_\_\_\_  
 " 0° C., 200 " 60 "  
 " 46.1° C., 50 " 5 "  
 Melting point, (° C.) \_\_\_\_\_  
 Ductility, \_\_\_\_\_° C., \_\_\_\_\_ cm. \_\_\_\_\_° C., \_\_\_\_\_ cm.  
 Loss at 105° C., 5 hours \_\_\_\_\_  
 Loss at 163° C., 5 hours \_\_\_\_\_  
 Characteristics of residue \_\_\_\_\_  
 Consistency of residue { Penetration 25° C., 100 grams, 5 seconds \_\_\_\_\_  
 Float test, \_\_\_\_\_° C., (seconds) \_\_\_\_\_; \_\_\_\_\_° C., (seconds) \_\_\_\_\_  
 Total bitumen (soluble in CS<sub>2</sub>) \_\_\_\_\_  
 Organic matter insoluble \_\_\_\_\_  
 Inorganic matter insoluble \_\_\_\_\_  
 Per cent of total bitumen insoluble in 86° B. naphtha \_\_\_\_\_  
 Fixed carbon \_\_\_\_\_  
 Residue of \_\_\_\_\_ penetration \_\_\_\_\_  
 Remarks: \_\_\_\_\_

Respectfully submitted,

(Title) \_\_\_\_\_

(Name and location of laboratory :)

## REPORT ON SAMPLE OF TAR.

(Classification name of material.)

Laboratory No. \_\_\_\_\_

(Date reported.) \_\_\_\_\_, 191\_\_.

Trade name \_\_\_\_\_

Identification marks \_\_\_\_\_

Submitted by \_\_\_\_\_ Title \_\_\_\_\_ Address \_\_\_\_\_

Sampled \_\_\_\_\_, 191\_\_ Received \_\_\_\_\_, 191\_\_

Sampled from \_\_\_\_\_

Quantity represented \_\_\_\_\_

Manufactured by \_\_\_\_\_

Location used or to be used \_\_\_\_\_

Examined for \_\_\_\_\_

## TEST RESULTS.

General characteristics \_\_\_\_\_

Water \_\_\_\_\_

Specific gravity, 25° C./25° C. \_\_\_\_\_

Specific viscosity, Engler at \_\_\_\_\_° C. \_\_\_\_\_

Float test, \_\_\_\_\_° C. (seconds) \_\_\_\_\_; \_\_\_\_\_° C. (seconds) \_\_\_\_\_

Melting point (° C) \_\_\_\_\_

Solubility in carbon disulphide \_\_\_\_\_

## DISTILLATION.

| Fractions.           | Character. | Per cent volume. | Per cent weight. |
|----------------------|------------|------------------|------------------|
| ..... 170° C. ....   |            |                  |                  |
| 170° C.-235° C. .... |            |                  |                  |
| 235° C.-270° C. .... |            |                  |                  |
| 270° C.-300° C. .... |            |                  |                  |
| Residue .....        |            |                  |                  |

Specific gravity of distillate 25° C./25° C. \_\_\_\_\_

Melting point of residue (° C) \_\_\_\_\_

Insoluble in dimethyl sulphate, per cent of fraction \_\_\_\_\_° C. to \_\_\_\_\_° C. \_\_\_\_\_

Remarks:

Respectfully submitted,

(Title) \_\_\_\_\_



(Name and location of laboratory:)

-----  
-----

REPORT ON SAMPLE OF PORTLAND CEMENT.

Laboratory No. \_\_\_\_\_ (Date reported.) \_\_\_\_\_, 191\_\_\_\_  
 Brand \_\_\_\_\_  
 Identification marks \_\_\_\_\_  
 Submitted by \_\_\_\_\_ Title \_\_\_\_\_ Address \_\_\_\_\_  
 Sampled \_\_\_\_\_, 191\_\_\_\_ Received \_\_\_\_\_, 191\_\_\_\_  
 Sampled from \_\_\_\_\_  
 Quantity represented \_\_\_\_\_  
 Manufactured by \_\_\_\_\_  
 Location used or to be used \_\_\_\_\_  
 Examined for \_\_\_\_\_

TEST RESULTS.

Chemical tests:

Loss on ignition, per cent. \_\_\_\_\_  
 Insoluble residue, per cent. \_\_\_\_\_  
 Sulphuric anhydride (SO<sub>3</sub>), per cent. \_\_\_\_\_  
 Magnesia (MgO), per cent. \_\_\_\_\_

Physical tests:

Specific gravity \_\_\_\_\_  
 Per cent retained on 200-mesh sieve \_\_\_\_\_  
 Steam test \_\_\_\_\_

|                   | Gillmore<br>needle. | or | Vicat<br>needle. |
|-------------------|---------------------|----|------------------|
| Initial set _____ | _____               | or | _____            |
| Final set _____   | _____               | or | _____            |

Tensile strength (1:3 Ottawa sand):

| 7 days. | 28 days. |
|---------|----------|
| _____   | _____    |
| _____   | _____    |
| _____   | _____    |

Average: \_\_\_\_\_ Average: \_\_\_\_\_

Remarks:

Respectfully submitted,

\_\_\_\_\_  
 (Title) \_\_\_\_\_

(Name and location of laboratory:)

## REPORT ON SAMPLE OF VITRIFIED PAVING BRICK.

(Date reported.)

Laboratory No. \_\_\_\_\_, 191\_\_  
 Trade name \_\_\_\_\_  
 Identification marks \_\_\_\_\_  
 Submitted by \_\_\_\_\_ Title \_\_\_\_\_ Address \_\_\_\_\_  
 Sampled \_\_\_\_\_, 191\_\_ Received \_\_\_\_\_, 191\_\_  
 Sampled from \_\_\_\_\_  
 Quantity represented \_\_\_\_\_  
 Manufactured by \_\_\_\_\_  
 Location used or to be used \_\_\_\_\_  
 Examined for \_\_\_\_\_

## TEST RESULTS.

*General data.*

Average dimensions, length \_\_\_\_\_ Width \_\_\_\_\_ Depth \_\_\_\_\_  
 Drying treatment \_\_\_\_\_

*Standardization data.*

|                       | Weight<br>of charge<br>(after<br>standard-<br>ization. | Number of fresh stave liners. | Repairs affecting barrel. |
|-----------------------|--------------------------------------------------------|-------------------------------|---------------------------|
| 10 large spheres..... | .....                                                  | .....                         | .....                     |
| small spheres.....    | .....                                                  | .....                         | .....                     |
| Total.....            | .....                                                  | .....                         | .....                     |

Number of charges tested since last inspection, \_\_\_\_\_.

*Running data.*

|                                         | Time readings. |          |          | Revolu-<br>tion<br>counter<br>readings. | Running<br>notes,<br>stops,<br>etc. |
|-----------------------------------------|----------------|----------|----------|-----------------------------------------|-------------------------------------|
|                                         | Hours.         | Minutes. | Seconds. |                                         |                                     |
| Beginning of test.....                  | .....          | .....    | .....    | .....                                   | .....                               |
| Final reading.....                      | .....          | .....    | .....    | .....                                   | .....                               |
| Initial weight of 10 bricks... ..       | .....          | .....    | .....    | Maximum variation in per cent loss,     |                                     |
| Final weight of 10 bricks... ..         | .....          | .....    | .....    |                                         |                                     |
| Loss of weight.....                     | .....          | .....    | .....    |                                         |                                     |
| Loss of weight, per cent.....           | .....          | .....    | .....    |                                         |                                     |
| Number of bricks broken in<br>test..... | .....          | .....    | .....    |                                         |                                     |

Remarks:

Respectfully submitted,

(Title) \_\_\_\_\_

## RECOMMENDED STANDARD METHODS OF SAMPLING.

---

### SAMPLING BROKEN STONE.

(1) *By whom taken.*—Samples are to be taken by the engineer or his authorized representative.

(2) *When taken.*—Samples are to be taken from the proposed source of supply at least ----- days before the stone is to be accepted or rejected, also from every ----- cubic yards quarried, or when the quality or appearance of the stone changes, and at such other times as may be directed by the engineer.

(3) *Where and how taken.*—

(a) Sampling for quality: Samples shall be taken either from the quarry or from cars as directed by the engineer, and shall be sound interior rock, representative of that which it is proposed to use. Mixed samples may be taken if deemed necessary by the engineer.

(b) Sampling for size: Samples of the crusher product shall be taken either at the crusher or from cars as directed by the engineer. The sample shall be mixed from runs of the crusher, on different days, or, if taken from cars, shall be taken from both ends and top and bottom of the car.

(4) *Amount and size of sample.*—

(a) Sampling for quality: A sample shall weigh between 25 and 40 pounds and shall consist of pieces of rock at least  $1\frac{1}{2}$  inches in size and one piece at least 3 by 4 by 6 inches, free from seams and cracks, and with bedding plane marked.

(b) Sampling for size: A sample for size shall weigh not less than 10 pounds for materials of three-quarters inch maximum diameter or less. Samples of materials of other sizes shall increase in weight to a maximum of approximately 60 pounds, varying with the size and weight of the largest pieces represented by the sample. The sample shall be representative of the product as delivered for use.

(5) *Marking and shipping.*—Samples shall be shipped in tight boxes or bags and shall be accompanied by a card in the container or securely attached thereto, stating date, by whom taken, by whom submitted, source of supply, exact location where sample was taken, proposed purpose to which the material is to be put, space for remarks, and in case of quarry investigations, owner, quantity available, amount and character of stripping, whether material from same source has been previously used, where and for what purpose, and with what results, haul to nearest point on road, average haul to job, character of haul, initial cost of rock.

Notification of sampling, containing the above data, shall be forwarded separately to the laboratory immediately upon taking the sample.

### SAMPLING BROKEN SLAG.

(1) *By whom taken.*—Samples are to be taken by the engineer or his authorized representative.

(2) *When taken.*—Samples are to be taken from the proposed source of supply at least ----- days before the slag is to be accepted or rejected, also from every ----- cubic yards quarried, or when the quality or appearance of the slag changes, and at such other times as may be directed by the engineer.



(3) *Where and how taken.*—

(a) Sampling for quality: Samples shall be taken either from the deposit or from cars, as directed by the engineer, and shall be representative of that which it is proposed to use. Mixed samples may be taken if deemed necessary by the engineer.

(b) Sampling for size: Samples of the crusher product shall be taken either at the crusher or from cars as directed by the engineer. The samples shall be mixed from runs of the crusher on different days, or, if taken from cars, shall be taken from both ends and top and bottom of the car.

(4) *Amount and size of sample.*—

(a) Sampling for quality: A sample shall weigh between 25 and 40 pounds and shall consist of pieces of slag at least  $1\frac{1}{2}$  inches in size, and one piece at least 3 by 4 by 6 inches.

(b) Sampling for size: A sample for size shall weigh not less than 10 pounds for material of three-quarters inch maximum diameter or less. Samples of materials of other sizes shall increase in weight to a maximum of approximately 60 pounds, varying with the size and weight of the largest pieces represented by the sample. The sample shall be representative of the product as delivered for use.

(5) *Marking and shipping.*—Samples shall be shipped in tight boxes or bags and shall be accompanied by a card in the container or securely attached thereto, stating date, by whom taken, by whom submitted, source of supply, exact location where sample was taken, proposed purpose to which the material is to be put, space for remarks, and, in case of source investigations, owner, quantity available, whether material from the same source has been previously used, where and for what purpose, and with what results, haul to nearest point on road, average haul to job, character of haul, initial cost of slag.

Notification of sampling, containing the above data, shall be forwarded separately to the laboratory immediately upon taking the sample.

NOTE.—The conference, recognizing that in general slag is not a uniform product, recommends that special care should be taken to get a representative sample.

#### SAMPLING STONE BLOCK.

(1) *By whom taken.*—Samples are to be taken by the engineer or his authorized representative.

(2) *When taken.*—Samples are to be taken at least \_\_\_\_\_ days before the block is to be accepted or rejected, or when the quality or appearance of the block changes, and at such other times as may be directed by the engineer.

(3) *Where and how taken.*—Samples shall be taken either from the quarry or from cars, as directed by the engineer. They shall be representative of the block which it is proposed to use; and no sample shall include blocks that would be rejected by a visual examination.

(4) *Amount and size of sample.*—The sample shall consist of at least 10 blocks. The bedding plane shall be marked on at least 2 blocks.

(5) *Marking and shipping.*—Samples shall be shipped in tight boxes and shall be accompanied by a card in the container, or securely attached thereto, stating date, by whom taken, by whom submitted, source of supply, exact location where sample was taken, proposed purpose to which the material is to be put, whether material from same source has been previously used, where and for what purpose and with what results, initial cost of block, haul to nearest point on road, average haul to job, character of haul, and space for remarks.

Notification of sampling, containing the above data, shall be forwarded separately to the laboratory immediately upon taking the sample.

## SAMPLING GRAVEL.

(1) *By whom taken.*—Samples are to be taken by the engineer or his authorized representative.

(2) *When taken.*—Samples are to be taken from the proposed source of supply at least ----- days before the gravel is to be accepted or rejected, also from every ----- cubic yards excavated, or when the quality or appearance of the gravel changes, and at such other times as may be directed by the engineer.

(3) *Where and how taken.*—

(a) Sampling at the pit: Enough samples shall be taken to represent an average of the material. An individual sample must be taken through a full vertical section of that material which it is proposed to use at the point selected. Each sample shall be taken from a freshly exposed vertical face.

(b) Sampling from cars, barges, etc.: Enough samples shall be taken, as directed by the engineer, to represent average composition. Samples from cars shall be taken from both ends and from top and bottom of the car.

(4) *Amount and size of sample.*—

(a) Sampling for quality: For screened gravel sample shall weigh 25 to 30 pounds. For bank gravel sample shall weigh 50 to 75 pounds.

(b) Sampling for size: A sample for size shall weigh not less than 10 pounds for materials of three-quarter-inch maximum diameter or less. Samples of materials of other sizes shall increase in weight to a maximum of approximately 60 pounds, varying with the size and weight of the largest pieces represented by the sample. The sample shall be representative of the product as delivered for use.

(5) *Marking and shipping.*—Samples shall be shipped in tight boxes or bags and shall be accompanied by a card in the container or securely attached thereto, stating date, by whom taken, by whom submitted, source of supply, exact location where sample was taken, proposed purpose to which the material is to be put, space for remarks, and, in case of pit or bank investigation, owner, quantity available, amount and character of stripping, whether material from same source has been previously used, where and for what purpose, and with what results, haul to nearest point on road, average haul to job, character of haul, initial cost of gravel.

Notification of sampling, containing the above data, shall be forwarded separately to the laboratory immediately upon taking the sample.

## SAMPLING SAND.

(1) *By whom taken.*—Samples are to be taken by the engineer or his authorized representative.

(2) *When taken.*—Samples are to be taken from the proposed source of supply at least ----- days before the sand is to be accepted or rejected, also from every ----- cubic yards excavated, or when the quality or appearance of the sand changes, and at such other times as may be directed by the engineer.

(3) *Where and how taken.*—Samples shall be taken from freshly exposed portions of the deposit as directed by the engineer. Mixed samples may be taken if deemed necessary.

In general, the number of samples shall be sufficient to cover the extreme variation of quality in that part of the deposit which is proposed to be used.

(4) *Amount and size of sample.*—Each sample, whether individual or composite, shall weigh between 10 and 15 pounds.

(5) *Marking and shipping.*—Samples shall be shipped in tight boxes or bags and shall be accompanied by a card in the container or securely attached thereto, stating date, by whom taken, by whom submitted, source of supply, exact location where sample was taken, proposed purpose to which the material is to be put, space for remarks, and in case of source investigation, owner, quantity available, amount and character of stripping, whether material from same source has been previously used, where and for what purpose, and with what results, haul to nearest point on road, average haul to job, character of haul, initial cost of sand.

Notification of sampling, containing the above data, shall be forwarded separately to the laboratory immediately upon taking the sample.

#### SAMPLING SEMI-GRAVEL, TOP SOIL, AND SAND CLAY.

Samples of materials of this class shall be of two kinds: Class I, samples of the raw material taken from the natural deposit; Class II, samples of the loose material after being mixed in place on the roadbed and before consolidation.

Class I sample shall be used simply as preliminary evidence of the suitability of the aggregate subject to admixture of one or more ingredients to adjust the composition to the limits set forth in the specifications.

The final acceptance of the material as satisfying the specifications shall be based on Class II samples.

*Standard containers.*—(1) A three-compartment box of pasteboard, wood, or metal, outside dimensions 5 by 10 by 10 inches; or (2) close woven bags or sacks of material which do not allow sifting out of fine particles, dimensions 6 inches wide by 12 inches long.

*Labeling.*—Each compartment in the box container must contain a label showing at what depth the contents were taken. The whole sample shall be accompanied by a card, securely attached thereto, stating date, by whom taken, by whom submitted, source of supply, exact location where sample was taken, position within the deposit where taken, owner, quantity available, amount and character of stripping, if any, whether material from same source has been previously used, where, and with what results, haul to nearest point on road, average haul to job, character of haul, initial cost of material.

When bag containers are used, one complete sample shall comprise 3 bags, each bag labeled as to depth from which the material is taken.

Each bag, or, if preferred, a larger receptacle containing the three bags, is to be labeled with the information detailed above.

*How to take Class I samples.*—For each 1 acre or less of area two samples must be taken, one a local sample and the other a composite sample.

The local sample is to be taken near the center of the area and is intended to represent the vertical average of the material at that point. It shall be taken in three layers, each layer ---- inches thick, according to the method described as follows:

The material is to be loosened over a 3 by 3 foot area to the specified depth, usually 4 inches. The loose material is to be intermixed with a shovel and the sample for one compartment of the box container or one of the bags is to be taken therefrom.

The remaining loose material is to be shoveled out and discarded. The second layer is to be loosened to equal depth, usually 4 inches, to be intermixed as before, and a second compartment or bag is to be filled. The same procedure shall apply to the third layer, and the filling of the third compartment or bag.

In exceptionally thick deposits the depth of each layer or the number of layers may be increased to cover the entire thickness of the deposit.



The composite sample is to be taken as follows: Roughly divide the area to be represented by the sample into squares not exceeding 50 feet in size. At the corners of all squares loosen a 3 by 3 foot area to a depth of \_\_\_\_<sup>1</sup> inches. Thoroughly mix the loose material. Carry an equal amount of the material from each such point to a central point and intimately mix the various samples. Not less than 200 pounds of material must be so mixed. From the center of the pile of mixed material fill a container and label for shipment.

Where the material occurs as a substratum sink no less than four 3 by 3 foot pits per acre or smaller area to intersect the material. Remove the covering and sample the exposed bed as for a local sample described above.

*How to take Class II samples.*—These are the most important samples, and should be taken by the engineer or competent inspector while work is in progress.

When the materials have been spread and intimately mixed in accordance with properly drawn clauses covering methods of construction, the engineer should fill a container at intervals of \_\_\_\_<sup>2</sup> feet, along the road, and also at such other points as his judgment may dictate, where evidence of unsatisfactory mixing is apparent.

Very prompt examination of these samples should be made in order that defects of composition may be remedied by the builder before consolidation has progressed.

#### SAMPLING BITUMINOUS MATERIALS.

*General recommendations.*—All samples should be selected to represent as nearly as possible an average of the material, care being taken that they are not contaminated with other materials. It is recommended also that special care be taken to forward the samples in clean, suitable containers, and wherever possible all materials should be sampled at the point of manufacture, and sufficiently in advance of shipment of the material represented to allow for the testing and reporting upon the sample before shipment. When impracticable to take samples at the point of manufacture they should be taken by the engineer or inspector, from the shipment immediately upon delivery.

In collecting samples, if there is any doubt of the homogeneity of the material it is recommended that individual samples be lifted as hereinafter described, and such samples should be forwarded to the laboratory, where tests should be conducted to determine the uniformity, after which a composite sample of equal parts of the individual samples may be mixed for complete tests.

Samples should be taken as frequently as necessary to insure the uniformity of the material.

*Marking samples.*—Samples should be marked for identification in such manner that the identification will not be removed in transit. Notification of sampling containing this identification, together with such other information as is required or of advantage to the laboratory, should be separately forwarded to the laboratory immediately upon taking the sample.

*Size of samples.*—No sample should be less than 1 quart, whether for complete testing or for individual test.

*Plant sampling.*—Drip samples are recommended. In taking drip samples, the pumping should be continued until sufficient time has elapsed to clean the line before sample is taken. The drip valve should be so regulated that the collecting of the material continues through the entire time of pumping.

---

<sup>1</sup> A depth of 8 inches is suggested.      <sup>2</sup> Intervals of 500 feet are suggested.

When impracticable to follow the above method it is recommended that samples be taken from the storage tank at three different levels.

Material in barrels or drums at a plant should be sampled by taking samples from not less than 3 per cent of the containers.

Whenever possible, the portion of the sample from each drum or barrel should be taken from near the heart of the barrel after it has been split open. Where samples must be taken from the top of the barrel, the material lying within three inches of the surface should not be included. A hatchet or any sharp-pointed tool is suitable for the purpose of digging into the barrel. (IMPORTANT.—Do not use kerosene on the blade.) The several portions are then to be pressed in a can of not less than one-quart capacity, using enough material very nearly to fill the can which is then tightly covered. If cans are not available and some other type of container used, they must be entirely free from paper or any other substance to which the bituminous material adheres readily.

Check field samples are recommended on plant inspected material.

*Field sampling.*—For barrel shipments, see plant barrel sampling.

*Sampling fluid products.*—When a fluid material is shipped in tank cars, and the sample is to be taken directly from the tank car to represent an average of the entire tank-car contents, the following method is suggested:

A tin can, with a tight-fitting removable cover and a wire handle, is secured, and a number of holes one eighth of an inch in diameter are punched in the cover. This bucket is then weighted in any convenient way and lowered slowly by means of a cord attached to the handle through the entire depth of the tank car, so that the can will be filled with material from all depths of the car. This can is then emptied into another can of at least 1 quart capacity having a screw top or other equally tight cap or cover. A sample is more representative when the tank car has been agitated before the sample is taken.

Where individual samples are desired to check the uniformity of material throughout a tank car, it is suggested that three samples be taken from top and middle and a third sample be taken from the outlet valve through which a sufficient amount of bituminous material has been allowed to flow in order to clean the valve properly.

*Semisolid products.*—Barrel shipments are to be sampled as in plant sampling.

Tank-car shipments are to be sampled through the dome by the use of a clean hot shovel.

*Bituminous aggregates.*<sup>1</sup>—It is suggested that a 5-pound sample be submitted when the material is sampled before being placed in the pavement.

Samples of pavements should be at least 1 square foot.

The material should be carefully boxed in order that it may remain intact during transit.

#### SAMPLING PORTLAND CEMENT.

Each shipment or lot of cement used on the work shall be sampled and tested in accordance with the standard specifications and tests for Portland cement given in the 1916 standards of the A. S. T. M. serial designation C9-17.

It is recommended that in sampling cars and bins the method specified in A. S. T. M. 1916 standard specifications for Portland cement, section 17 (b)

<sup>1</sup> The term "bituminous aggregate" is defined as follows: The mineral or other aggregate, together with the bitumen which is used as the cementing medium.

be followed, using composite samples. Samples at the mill shall be taken by any of the methods of section 18, A. S. T. M. specifications, as may be most practicable.

#### FIELD SAMPLES OF CONCRETE.

(1) *When taken.*—Samples shall be taken regularly for the general control of strength and uniformity on one day of each week of work; and at irregular intervals, whenever a complete change is noted in the character or grading of one or more materials or in any element affecting the entire mix.

(2) *Number of samples.*—

(a) In taking regular samples three specimens should be molded to be broken one at each of the periods, 14 days, 28 days, and -----.

(b) In taking irregular samples, nine specimens should be molded, three to be broken at each of the periods, 14 days, 28 days, and -----.

*How taken.*—The batch sampled for general purpose should be similar in consistency and general grading of the aggregate to the regular run of batches being turned out. The sample from which specimens are molded should be composed of several portions taken during the discharge of one batch in order to represent an average of the batch; or the batch may be dropped upon the subgrade and concrete from several points (taking care to exclude dirt), placed in a clean wheelbarrow or other container, avoiding additional mixing.

#### SAMPLING VITRIFIED PAVING BRICK.

*Inspection.*—Vitrified brick may be inspected and tested at the point of manufacture, or they may be sampled at the point of delivery, and representative samples submitted to the laboratory for testing prior to acceptance of the shipment.

*Plant inspection.*—Whenever practicable the inspection and testing of vitrified brick shall be carried on at the manufacturer's plant. The choice between plant inspection and sampling at point of use should be based on the average number of brick to be shipped from the plant per day, and the total number required for the particular piece of work.

Whenever conditions permit, samples should be taken directly from the kiln during the process of emptying. One or more sets of tests, depending upon the size of the kiln, each set consisting of three separate tests, should be made on each kiln. Each test in a set of three should represent approximately a single degree of burning (based on the position of the bricks in the kiln), and all ten of the bricks in a single test should be of the same approximate degree of burning.

The average abrasion loss in three such tests will determine whether the contents of a kiln or part of a kiln meet the average maximum abrasion loss specified; and the maximum variation between the per cent abrasion losses of the three sets will be used to determine what portion of the bricks represented will be culled or rejected.

*Sampling from piles at the plant.*—In general, samples selected from piles at the plant shall be as nearly as possible representative of the entire run of the brick. Samples from piles shall be taken from as many different points corresponding to the length, breadth, and depth of the pile as possible. In no case shall they be confined to the upper or outer few layers. Where controversy arises regarding the admissibility of certain types or portions of the lot, entire test samples may be selected from such types or portions having a characteristic appearance in common.



*Sampling at point of delivery.*—A representative sample should be taken from each carload received. Considerations covered under "Sampling from piles at the plant" apply equally to sampling from cars.

*Shipping.*—Samples shipped by freight or express to the laboratory shall be put up in packages containing twelve bricks each, packed in two rows separated by a partition for protection.

*Condition of bricks before testing.*—If bricks are damp, they shall be dried at a temperature of 100° F. before testing. No bricks shall be included in the test lot which would be rejected on the basis of cracks, chips, or other defects covered by the specification clauses for visual inspection.

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## INDEX ACCORDING TO TYPE OF ROAD.

In this report the specifications have been grouped according to the types of materials covered. The following index has been prepared for the convenience of engineers who may be particularly interested in individual types of construction. In this index all specifications relating to each type of pavement are grouped together.

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# UNITED STATES DEPARTMENT OF AGRICULTURE



## BULLETIN No. 556

Contribution from the Forest Service  
HENRY S. GRAVES, Forester



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PROFESSIONAL PAPER

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## MECHANICAL PROPERTIES OF WOODS GROWN IN THE UNITED STATES.

By J. A. NEWLIN, *In Charge of Timber Tests*, and THOS. R. C. WILSON, *Engineer in Forest Products*.

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### PURPOSE OF THE STUDY.

This publication on the mechanical properties of wood makes available for general use data which will serve as a basis for (1) the comparison of species, (2) the choice of species for particular uses, and (3) the establishment of correct working stresses.

The increasing scarcity of many species of timber which had become more or less standard in various wood-using industries is opening the field for other species. Through long use the properties which make the standard species valuable for a particular purpose are quite well understood, but it is doubtful if many manufacturers know to what extent other species possess those same qualities and to what extent they might replace the standard species. Present conditions will not permit long, tedious, and expensive experiments with commercial forms to establish new species in the industries; and to avoid this it is necessary to have definite information and data on both the new and the old species. With such test data at hand it is possible to compare the properties of a known species with those of any other. The possibility of substitution generally reduces to the few species which possess qualities approaching those previously in use. If the



properties making a particular wood valuable for a certain purpose are known, the comparison is made the easier.

As an example of the foregoing, suppose it is desired to find a wood for flooring for use in the place of maple. For flooring, hardness is the ruling factor, providing, of course, the wood possesses other strength properties to a reasonable degree. Using hardness as a basis for comparison, white oak should be as good or better than maple for flooring, which is true. Using modulus of rupture, which is a very important strength value in structural material but of very little importance in flooring, as a basis for comparison, longleaf pine or Douglas fir would unjustly be given preference to oak.

In addition to their value in expediting the search for substitute woods, the data presented in this bulletin are of use to manufacturers and others in furnishing definite information concerning the properties of all commercial woods. This information is used in many different ways, several of which are briefly discussed in the following paragraph.

In the preparation of specifications and grading rules for structural timber it is essential to know the relation between physical and mechanical properties, and the results of the tests here reported have been used by a number of associations and societies in preparing such rules. They are also used by architects and engineers in determining safe working stresses for wood in structures, in connection with tests upon full-sized members. In the case of new uses for wood, which frequently arise in special constructions, such as airplanes, for instance, these data are of much help in selecting the species which have the specific properties best fitting them for these uses.

In order to cover the ground successfully, this bulletin must furnish information on all mechanical properties of wood; and with that end in view no effort has been spared in making a complete compilation of the information at hand. There are few uses of timber where at least some of the properties given in the table are not of importance.

The Forest Service tests are standardized and the data contained herein on any one species are directly comparable with similar data on any other species listed. These tests obviously eliminate a great amount of duplication which would result from individual investigations. Industries anxious to find new species to supplant waning supplies of present material would doubtless make tests adapted to their own particular purpose which would probably throw no light on other properties valuable for uses not in their line. In many cases the tendency would be to keep secret such findings in order to meet more effectively competition from other firms; and even though the data from all such individual tests were available, an intelligent comparison of species could not be made because of the lack of standardization of methods of test.

## SCOPE AND METHOD OF EXPERIMENTS.

## ORIGIN OF DATA.

The data in this bulletin are based upon about 130,000 tests, probably the greatest number ever made in one series upon any material. For this reason, and for others explained later, the data are the most thorough and accurate that are available on the mechanical properties of American woods. The tests were begun about six years ago at the Forest Products Laboratory, which is maintained by the United States Forest Service with the cooperation of the University of Wisconsin. One hundred and twenty-six species of wood have been tested, and it is planned to continue the series until all species which are important, or which give promise of becoming so, have been included.

## SMALL CLEAR SPECIMENS USED.

Small clear specimens are used in the tests in order that consideration of the influence of defects may be eliminated from calculations to determine the relation between strength and density, moisture, locality of growth, soil conditions, etc. These various relations are referred to in the present bulletin, however, only when it is necessary in order to render the data thoroughly understandable. The specimens are 2 by 2 inches in cross section. Bending specimens are 30 inches long; others shorter, depending on the kind of test.

## SELECTION OF MATERIAL.

The material for any given species and locality is cut from typical trees, usually five in number. These are selected by representatives of the Forest Service, careful descriptions being made of each tree and of the conditions under which it has grown. As a rule the test specimens are taken from the top 4 feet of the 16-foot butt log. The number of test specimens from each tree varies from 40 to 120, depending on the size of the tree. Eventually each important species will be represented by tests from at least five typical trees from each of several localities distributed throughout its range of growth.

## OTHER DATA INCLUDED.

Data derived from tests previously made by the Forest Service and under practically the same conditions as the present series are included in Tables 1 and 2. The tests were made at Purdue University and at the Universities of Colorado, California, and Washington in cooperation with those institutions.

## TESTS ON LARGE TIMBERS.

A large number of tests have also been made by the Forest Service on full-sized timbers, such as bridge stringers, factory-building timbers, and car sills. These tests have demonstrated the influence of defects such as knots, shakes, and checks on strength, and they serve

as a guide to the use of data from tests on small specimens in establishing working stresses and grading rules for structural timbers. The results of tests of this kind on a number of species have already been published. (See list of publications, p. 46.)

#### PRECAUTIONS TO BE OBSERVED IN THE USE OF THE DATA.

Careful attention must be given to the natural variability of timber in order to make correct use of timber-test data. The following suggestions are offered as a guide to the use of the data given herein. Definitions of the various technical terms, with illustrations, are given on pages 7 to 18.

#### COMPARISON WITH DATA IN OTHER PUBLICATIONS.

In comparing the data in this publication with those in other publications, it must be kept in mind that scarcely any two series of tests have been made under the same conditions and that very frequently so little is specified concerning the character of the material and the methods of test as to make close comparisons impossible. A specific instance is furnished by the results of Sargent's tests<sup>1</sup> and those given in Forest Service Circular 15. These two publications are chosen as illustrations because of the numerous attempts which have been made to compare the figures in them with each other and with those obtained under the present series. Sargent made about 2,700 tests on 300 species of American woods; but he did not take into account what may have been relative large variations in moisture content, and he selected his specimens from the lower end of the butt logs—in most cases the best although most variable portion of the tree. The lack of data upon moisture content is an insurmountable barrier to comparison with the present series, since differences of moisture content between two groups of tests may be sufficient to cause as much as 100 per cent difference in the strength data. Circular 15, "Summary of Mechanical Tests on Thirty-two Species of American Woods," containing the results of about 30,000 tests, takes moisture into consideration, but allows of no comparison with the present series because of the selection of material with defects as found in the tree. Since no record of the extent or position of these defects in the test piece are now available, no estimate can be made as to the strength of the clear wood.

Data from other publications of the Forest Service which are known to be strictly comparable to those obtained from the present series of tests are included in Tables 1 and 2. The reader is cautioned against any attempt at the comparison of the data in this publication with those in any previous one dealing with tests on small clear pieces.

<sup>1</sup> Made for the Tenth United States Census, and results published in Vol. IX of the Tenth Census Reports.



Also, in making comparisons, it is important that the data should really be representative of the classes of material which it is proposed to compare. For example, it is not just to take the figures derived from Rocky Mountain Douglas fir, which is known to be inferior to the Pacific coast type,<sup>1</sup> as representative of the coast fir. Nor in general can a comparison of species properly be made from results of tests on large timbers alone; for in practically all cases the large timbers tested have not been selected as representative of the species, but have been chosen to determine the effect of defects, the effect of preservative treatment, or for the solution of other and similar problems.

Comparisons should not be made with greater refinement than the data justify. The change which additional tests would probably make in the average values and the probable variation of a given stick or lot of material from these average values should be considered. Numerical measures of these probable variations are given in Table 3.

#### CAUSES OF VARIATIONS IN STRENGTH.

Variations in strength of timber can be accounted for more accurately than is usually supposed. In some species there is a difference in strength in wood from different positions in the tree, different localities of growth, etc. But such variations have been overestimated, and a knowledge of them is not essential in order to estimate with a fair degree of accuracy the properties of a piece of timber. Differences in strength are usually due to differences in defects, moisture content, or density, or to combinations of these.

Defects are not considered in this publication. Their effects on structural timbers are discussed in Forest Service Bulletin 108; and limitations on their size, character, and location are given in the grading rules for structural timber which have been recommended by the Forest Service.<sup>2</sup>

Differences of moisture content cause considerable variation in the strength values of air-dry or partially air-dry material, but have no effect as long as all material is thoroughly green.

One of the principal factors causing differences in strength is variable density. As might be expected, the greater the density of a given stick or the more wood it has <sup>3</sup> per unit volume, the stronger is the stick.

<sup>1</sup> See also "Localities Where Grown," p. 8.

<sup>2</sup> See "Discussion of the Proposed Forest Service Rules for Grading the Strength of Southern Pine Structural Timbers," by H. S. Betts, Proceedings of Am. Soc. for Test. Materials, Vol. XV, 1915, p. 368.

<sup>3</sup> Accurate determinations made at the Forest Products Laboratory on seven species of wood, including both hardwood and coniferous species, showed a range of only about 4½ per cent in the density of the wood substance, or material of which the cell walls are composed. Since the density of wood substance is so nearly constant, it may be said that the density or specific gravity of a given piece of wood is a measure of the amount of wood substance contained in it.

## MISUSE OF TERMS.

Considerable confusion often arises from the use of general terms in a limited sense, or with different meanings by different persons. For instance, strength, in the broad sense of the word, is the summation of the mechanical properties or the ability of a material to resist stresses or deformations of various sorts. While such properties as hardness, stiffness, and toughness are not always thought of in connection with the term "strength," they are unconsciously included when, in a specific instance, they are important. This may be illustrated by some comparisons of oak and longleaf pine. For floor beams or posts, the pine, because of its strength and stiffness as a beam, has a slight advantage over the oak and is considered "stronger." For handles, vehicle or implement parts, oak, because of its greater toughness, or shock-resisting ability, is decidedly superior to the pine and is considered "stronger." Thus it is seen that the term "strength" may refer to any one of many properties or combinations of properties, and is necessarily indefinite in meaning unless so modified as to indicate one particular thing. To say, then, that one species is stronger than another is a meaningless statement unless it is specified in what particular respect it excels.

The term strength, in its more restricted sense, is the ability to resist stress of a single kind, or the stresses developed in one kind of a constructional member, as strength in shear, strength in compression, strength as a beam, strength as a column. Used in this way, the term is specific and allows no chance of confusion.

## RELATION OF PROPERTIES TO USES.

There are many properties of wood, such as taste imparted to foodstuffs, odor, ease of working, ability to take finish and to maintain shape, resistance to decay, etc., which, of course, are not given in the accompanying tables, but which are very important in some uses to which timber is put. In very few instances will strength data of themselves be sufficient to determine the value of a species for a given use.

There are few, if any, cases in which two species have all the various properties to the same degree or in the same relative proportion. This fact accounts for the special uses of the different species and for the difficulty in finding substitutes for certain species in particular uses. Confusion arises from comparing species for a certain use upon the basis of properties or strength values which are not of first importance in that use. The most important strength values are: In large beams, modulus of rupture, modulus of elasticity, and shear; in long columns, modulus of elasticity and crushing strength in compression parallel to grain; in material for spokes, tongues, or poles, ax handles, etc., modulus of rupture, modulus of elasticity, work to

maximum load in static bending, and height of drop in impact. In flooring, the desirable properties are hardness and slight shrinkage.

#### DATA ON GREEN TIMBER.

Table 1 gives the values obtained from tests on green material. It will be noted that there is a large variation in the moisture content of the various species. All, however, were tested at approximately the moisture content of the living tree and are well above the limit below which differences in moisture content produce differences in strength. Table 1 is more reliable than Table 2, because it is based on a much larger number of tests and on tests which are not influenced by variations in moisture content.

#### DATA ON AIR-DRY TIMBER.

Table 2, which gives the values obtained in tests of air-dry timber, should be considered as supplementary to Table 1. This table is necessary because the properties of all species are not changed in the same proportion by drying and all the properties are not equally affected.

Some of the properties of air-dry wood are subject to rapid change with change in moisture content. For this reason it is necessary in comparing species on the basis of Table 2 to make proper allowance for whatever differences may be shown in the column of moisture content. Table 3 includes figures showing the approximate changes which are made in the various properties of air-dry wood by the addition or subtraction of 1 per cent of moisture.

It will be noted from Tables 1 and 2 that in most properties the dry material excels the green. In structural design, however, no allowance should be made for such increase in strength, because in large timbers it is a very indefinite quantity. The increased strength of the wood fibers is usually offset by checks and other defects resulting from drying. Moreover, many structural timbers are subject to moisture changes, and the outer fibers may at any time become wet enough to reduce the mechanical properties to the level of those of green timber. For these reasons the strength of green material should be made the basis of stresses to be used in structural design.

#### EXPLANATION OF TABLES 1 AND 2.

(See tables on pp. 27 and 37.)

##### NAMES OF SPECIES.

Many of the species have numerous common names, and not infrequently one common name is applied to several species. This leads to so much confusion that it is necessary to refer to a standard nomenclature. The common and botanical names used in the tables are those given in Forest Service Bulletin 17, "Check List of the Forest Trees of the United States."



## LOCALITIES WHERE GROWN.

In the second column of the tables are listed the States in which the test specimens originated. The locality of growth has in some cases an influence on the strength of timber. This influence is, however, usually overestimated; just as great differences exist ordinarily between stands of different character grown in the same section of the country as between stands grown in widely separated regions. For this reason it is considered better to average the various localities together. Douglas fir, however, has not been averaged in this manner. Silviculturists have recognized that there are two well-marked types<sup>1</sup> and various intergradations of Douglas fir. Strength tests confirm this fact and show that there is actually a difference in strength between the Rocky Mountain and Pacific Coast types of Douglas fir. For this reason averages are given for the Coast and for the Rocky Mountain regions rather than for the species as a whole.

## NUMBER OF TREES.

The number of trees from which test specimens were taken is given in the third column of Table 1. As previously mentioned, five is the usual number from a single locality.

## NUMBER OF RINGS PER INCH.

Rings per inch is an inverse measure of the rate of growth. It is taken along a radial line on the end section of each specimen. One ring, consisting of a band of springwood and a band of summerwood, is formed by each year's growth; consequently, few rings per inch indicate fast growth, and vice versa.

Rate of growth is extremely variable, and the values given are to be taken as averages of the material tested only. Rate of growth has no definite relation to strength in the sense of strength being in proportion, either directly or inversely, to the rate of growth. Timber of any species which has grown with exceptional slowness is usually below the average of the species in strength values. In the coniferous species material of very rapid growth is also very likely to be below the average in strength. Among many of the hardwood<sup>2</sup> species, however, timber of rapid growth is usually above the average in strength properties.

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<sup>1</sup> See Forest Service Circular 150, "Douglas Fir: A Study of the Pacific Coast and Rocky Mountain Forms."

<sup>2</sup> A broad classification of timber species divides them into two groups: (1) Angiosperms, or trees with broad leaves, usually deciduous, the so-called "hardwoods"; (2) gymnosperms, or trees with needle or scalelike leaves, usually evergreen, most of them cone bearing, the so-called "softwoods." The two groups are popularly spoken of as "hardwoods" and "softwoods," or "hardwoods" and "conifers." The terms "hardwoods" and "softwoods" are therefore indicative of botanical classification and are not descriptive of the quality of the wood with respect to hardness. Such "hardwoods" as basswood and aspen are low in the scale of hardness; while the southern pines, tamarack, larch, and others, although called "softwoods," are quite hard.

## SUMMERWOOD.

The amount of summerwood is expressed in per cent of the entire cross section. (See definition of summerwood, p. 23.) It is measured along a representative radial line.

In many species the proportion of summerwood is indicative of the density; and different proportions of summerwood are usually accompanied by different densities and strength values. When the change from springwood to summerwood is not marked or the contrast between them is not sharp, no accurate measurement can be made and the results have no practical value.

In southern yellow pine and Douglas fir, one-third or more summerwood, except when associated with rapid irregular growth, indicates material of a quality suitable for use as structural timber.

## MOISTURE CONTENT.

Moisture content is the weight of water contained in the wood, expressed in per cent of the oven-dry weight of the wood. Moisture content is determined by weighing a small section of the test specimen and then drying it at 100° C. in freely circulating air until its weight becomes constant; the loss of weight is then divided by the dry weight to give the proportion of moisture, and this is usually expressed in per cent of the dry weight. Consequently, "moisture" as determined includes any other substances besides water volatile at 100° C. which may be in the wood.

The various species differ widely as to the amount of moisture contained in the wood of the living tree. For example, white ash and black locust are always comparatively dry; black ash and the oaks have about twice, and chestnut and buckeye three times, as much water as white ash. The coniferous species also show wide range in moisture content. White and red cedars are comparatively dry; cypress and white fir contain large amounts of water.

Moisture content sometimes varies with position in the tree. Most coniferous species have a large proportion of moisture in the sapwood and a much smaller proportion in the heartwood. In some the heartwood is very wet at the base of the tree, but comparatively dry higher up. Most hardwoods, or broad-leaved species, show a fairly uniform distribution of moisture throughout the tree.

## SPECIFIC GRAVITY.

Specific gravity is the weight of any given substance divided by the weight of an equal volume of pure water at its greatest density.

Obviously, the weight of wood in a given volume changes with the shrinkage and swelling caused by changes in moisture. Consequently, specific gravity is an indefinite quantity unless the circumstances under which it is determined are specified. Each of the columns

of specific gravity figures given in this table is based on the weight of the wood when oven dry and on its volume when green or at a specified stage of drying.

SPECIFIC GRAVITY BASED ON VOLUME WHEN GREEN.

In the determination of the figures for specific gravity based on volume when green the test specimens are weighed and measured when green. Their oven-dry weight is then computed by dividing the weight when green by 1 plus the proportion of moisture, moisture being determined as described in previous paragraphs. The specific-gravity data based on green volume are more reliable than the data based on air-dry or oven-dry volume because they are based on the largest number of determinations, and these determinations are unaffected by the shrinkage of the wood. Specific gravity so determined is, aside from actual strength data, the best criterion of the strength of clear wood of any species.

It has been found that in oak, more than in any other species or group of closely related species, pieces of the same density may vary widely in mechanical properties. Occasional very dense pieces of oak are for some unknown reason low in strength; but in all species specimens of low density are invariably weak.

SPECIFIC GRAVITY BASED ON AIR-DRY VOLUME.

Specific gravity based on air-dry volume is obtained in the same manner as that based on volume when green, except that the volume measurements are made after the material has been air dried. The data in the tables are less reliable than those for the specific gravity on green volume because they are based on fewer determinations and are affected by variations in the shrinkage which has taken place.

SPECIFIC GRAVITY BASED ON OVEN-DRY VOLUME.

In determining the specific gravity based on oven-dry volume, the volume as well as the weight is taken after the specimens are dried to a practically constant weight in air at 100° C. The difference between specific gravity based on green volume and that on oven-dry volume is due to the shrinkage, and one may be determined from the other if the shrinkage in volume is known. Specific gravity on oven-dry volume = specific gravity based on volume when green  $\div$  (1 - the shrinkage.)

The specific gravity based on volume when oven dry and the shrinkage in volume (see columns 8 and 10, Table 1) determinations were made on the same specimens, of which there were usually four from each tree. The specific gravity based on green volume was determined from a much larger number of specimens and is consequently somewhat more reliable. Because these two specific gravities were



determined from different specimens the equation given at the end of the preceding paragraph does not hold exactly when applied to the data in columns 7, 8, and 10 of Table 1.

#### WEIGHT PER CUBIC FOOT.

Weight per cubic foot, like specific gravity, is a very indefinite quantity unless the circumstances under which it is determined are specified. The variability is also large, as may be realized from a consideration of the following: The specific gravity of some specimens may be twice that of others of the same species; occasionally a piece may contain nearly as much resin as wood; the moisture content may be as little as 4 or 5 per cent of the dry weight of the wood in the case of kiln-dry lumber, or it may be as great as 200 per cent in green timber, as is occasionally the case in the sapwood of some of the coniferous species.

#### WEIGHT PER CUBIC FOOT GREEN.

Weight per cubic foot green is the weight per cubic foot of the wood (including moisture) as it comes from the living tree. The various species differ largely as to the wetness of the green wood. The hardwoods as a rule do not exhibit any considerable variation with the position in the tree. The conifers, on the other hand, show a wide variation in moisture content between the heartwood and sapwood and, in some instances, between wood from the upper and lower parts of the tree. Tamarack and cypress, however, have a comparatively uniform moisture content throughout the tree. Sugar pine and western larch are frequently very heavy because of moisture and resin at the butt. Longleaf pine and some other species have a very low moisture content in the heartwood, while the sapwood is very wet. When this is the case, young thrifty trees with a large proportion of sapwood are much heavier than old overmature trees with a small amount of sapwood.

Variations of 4 per cent above or below the averages given are to be expected in any lot of material of a species which has fairly uniform moisture content. If the species is one that does not have a uniform distribution of moisture, about twice as great a variation may be expected. Under exceptional conditions the weight of green timber of some of the conifers may vary as much as 30 per cent from the average.

#### WEIGHT PER CUBIC FOOT AIR DRY.<sup>1</sup>

The weights given for air-dry wood are for wood with 12 per cent moisture. A variation of 4 per cent in any given lot of material even at this moisture content is to be expected. Large timbers

<sup>1</sup>See definition of air dry (glossary, p. 20).

ordinarily have more than 12 per cent moisture and average from 10 to 15 per cent heavier than the listed weights.

#### SHRINKAGE FROM GREEN TO OVEN DRY.

When wood is dried below the fiber saturation point (see glossary, p. 21), shrinkage begins and continues until the moisture is all driven off. Shrinkage along the length of timber is very small. Shrinkage in directions at right angles to the grain is very much greater and varies from 2 or 3 per cent to about 20 per cent. Radial shrinkage is about three-fifths as great as tangential shrinkage (see glossary, pp. 22 and 23.) Shrinkage in volume is of course the resultant of shrinkages along the fibers and in the radial and tangential directions. However, shrinkage in volume and radial and tangential shrinkages were independently determined in the present series of tests. The first was determined from four specimens, and each of the others from one specimen from each tree.

All shrinkages given are expressed in percentages of the original or green dimensions, and are total shrinkages to zero moisture. Shrinkage to an air dry condition of about 12 per cent moisture is sometimes more and sometimes less than half the total shrinkage. At about 12 per cent moisture the volume changes by about one-half of 1 per cent for each moisture content change of 1 per cent. Shrinkage in volume is important in measuring cordwood.

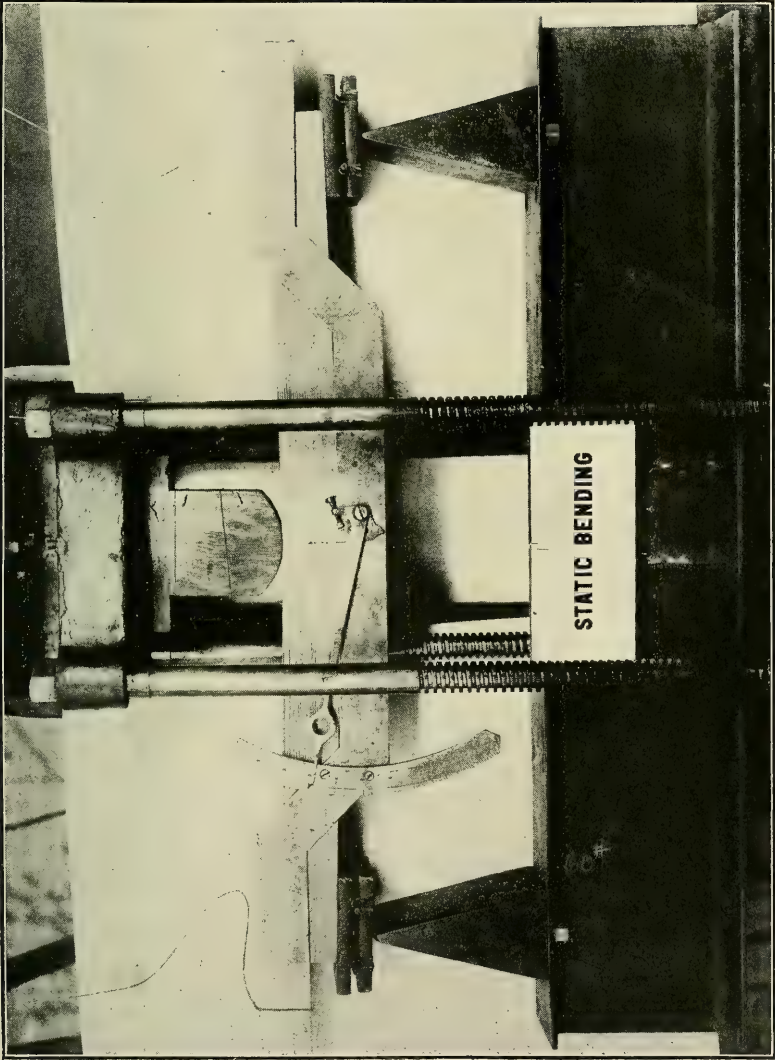
Radial shrinkage is the measure of the change in width of a quarter-sawed or edge-grain board. In most species at about 12 per cent moisture a moisture content change of 1 per cent may be expected to cause a change of about three-sixteenths of 1 per cent in the width of such a board. This is equivalent to three thirty-seconds of an inch change in the width of a 10-inch board for a 5 per cent change in moisture ( $5 \times \frac{3}{16}$  per cent of 10 inches =  $\frac{3}{2}$  of an inch).

Tangential shrinkage is the measure of the change in width of a flat sawed board. At about 12 per cent moisture a moisture content change of 1 per cent may be expected to cause a change of about five-sixteenths of 1 per cent in the width of such a board, which is equivalent to five thirty-seconds of an inch change in the width of a 10-inch board for 5 per cent change in moisture.

Both radial and tangential shrinkages are important in flooring, fixtures, and any construction which is to remain well joined under changing atmospheric conditions.

#### STATIC BENDING.

In the static bending test a 2 by 2 by 30 inch beam is supported over a 28-inch span. Loading is applied to its center and at a constant rate of deflection until the beam fails. Readings of load and deflection are taken simultaneously.



STATIC BENDING TEST.





The values derived from this test are applicable to beams of any size by the use of the formulæ given on page 24, except for the defects that occur in the larger sizes.

In all cases it is best to use the results from tests of green material in determining allowable working stresses in large timbers, since defects are usually introduced in drying large timbers with the result that often there is no increase of strength. However, timbers which are always dry may be allowed a slightly higher stress than those exposed to the weather or subject to moisture.

#### FIBER STRESS AT ELASTIC LIMIT.

Fiber stress at elastic limit (see definition, p. 21) is very important in determining the proper working stresses for a beam. A beam loaded to its elastic limit in static bending for a short time will recover its form immediately upon removal of the load. If the same load is allowed to remain, complete failure will ultimately result. Consequently, the necessity of keeping working stresses below the elastic limit is apparent. It is recommended, however, that working stresses be calculated not from the elastic limit, but from the modulus of rupture, and for the following reasons: There is a personal element in determining the elastic limit; slight inaccuracies in measurements of deflections often cause considerable error in elastic limit values; defects in structural timbers may be such that, in testing, certain portions are stressed to or beyond the elastic limit without discovery; and there is an element of safety in the differential of strength between the elastic limit and modulus of rupture values.

#### MODULUS OF RUPTURE.

Modulus of rupture is the computed fiber stress in the outermost fibers of a beam at the maximum load and is a measure of the ability of a beam to support a slowly applied load for a very short time. The formula by which modulus of rupture is computed is the same as that for fiber stress at elastic limit, the maximum load being substituted for the elastic limit load. The assumptions on which this formula are based hold only up to the elastic limit, hence modulus of rupture is not a true fiber stress. It is, however, a universally accepted term, and the values are quite comparable for various species and sizes of timber. It is a definite quantity, and the personal factor does not enter to any great extent into obtaining it. It is consequently not so subject to error as the fiber stress at elastic limit, and for that reason is used more than any other value to represent the strength of wood. Modulus of rupture should always be considered in calculating the strength of beams to be used as stringers, floor joists, etc. A green structural timber, if compara-

tively free from defects, can be expected to have a modulus of rupture about three-fourths as large as that of small clear pieces cut from it.

The modulus of rupture of small clear individual pieces will occasionally vary more than 40 per cent above or below the average modulus of rupture. Pieces giving very low values are almost invariably lacking in density, while very strong pieces are exceptionally dense.

Figures on the variation of modulus of rupture are given in Table 3.

Safe working stresses for carefully selected structural timbers, with all exceptionally light pieces excluded, subjected to bending in dry interior construction and where only small deflections are allowable are about one-fifth the modulus of rupture values given in the table for green material. (Table 1.) In some interior construction where beams may be allowed to sag somewhat without damage, the working stresses may be slightly increased. But for timbers used in bridges or other structures exposed to moisture, the working stress should be slightly lower. However, beams can not be correctly designed on the basis of outer fiber stress in bending alone. Strength in longitudinal shear must also be taken into account. (See p. 17 for allowable shearing stress.)

#### MODULUS OF ELASTICITY.

The modulus of elasticity is a measure of the stiffness or rigidity of a material. In the case of a beam modulus of elasticity is a measure of its resistance to deflection. The formula (see p. 24) connecting modulus of elasticity, load, and deflection shows that the deflection under a given load varies inversely as the modulus of elasticity; that is, a beam with a high modulus deflects but little. Modulus of elasticity is of value in computing the deflections of joists, beams, stringers, etc., and in computing safe loads for columns. The values given are derived from the static bending test, but are applicable to both beams and columns.

In building construction the means by which the various members are held in place, inequalities in workmanship on the various parts, differences in the quality of the timber in all parts of the structure, and shrinkage due to the adjustment of the moisture content of the various members to that of their surroundings give rise to unequalized local stresses, often very large. When these stresses become equalized through the gradual readjustment of the members, deflections greater than those calculated from the average moduli of elasticity will be found. For this reason it is good practice in the design of structures to use values for moduli of elasticity about one-half those given in Table 1.



## WORK TO ELASTIC LIMIT.

Work to elastic limit in static bending is a measure of the work which a beam is able to resist or the shock which it can absorb without being stressed beyond the elastic limit as determined under slowly applied loads.

## WORK TO MAXIMUM LOAD.

Work to maximum load in static bending represents the ability of the timber to absorb shock with a slight permanent or semi-permanent deformation and with some injury to the timber. Wood, especially in small sizes, can be bent somewhat beyond its elastic limit with only slight injury if the load is removed at once. Work to maximum load is a measure of the combined strength and toughness of a material under bending stresses. Superiority in this quality is the characteristic which makes hickory better than ash, and oak better than longleaf pine, for such uses as handles and vehicle parts. Many species yield butt cuts that exceed upper cuts in combined strength and toughness, hickory showing this characteristic most markedly. The superiority of butt cuts of hickory to upper cuts for ax handles is well known to experienced woodsmen.

## IMPACT BENDING.

The impact bending test is made upon a beam 2 by 2 by 30 inches over a 28-inch span. A 50-pound hammer is dropped upon the stick at the center of the span, first from a height of 1 inch, next 2 inches, etc., up to 10 inches, then increasing 2 inches at a time until complete failure occurs. The deflections of the specimen are recorded on a revolving drum by a pointer attached to the hammer. This pointer also records the position the specimen assumes after the shock. Thus data are obtained for determining the various properties of the wood when subjected to shock.

## FIBER STRESS AT ELASTIC LIMIT.

Fiber stress at elastic limit is the greatest stress to which a timber may be subjected under impact loading and recover immediately. Fiber stress at elastic limit in impact is approximately double the fiber stress at elastic limit in static bending. This is an expression of the fact that a small beam, if suddenly strained, bends approximately twice as far to the elastic limit as when loaded slowly. (See also fiber stress at elastic limit, p. 13.)

## WORK TO ELASTIC LIMIT.

Work in bending to the elastic limit in impact is a measure of the ability of a timber to absorb shock and recover therefrom immediately and without injury. The values apply only to resistance

to falling bodies or to other conditions in which the stress is applied and relieved in one-twenty-fifth of a second or less. It represents a quality important in tool handles and in athletic goods, such as baseball bats.

#### HEIGHT OF DROP.

Height of drop is the maximum or last drop of the hammer. It represents a quality important in articles which are occasionally stressed under a shock beyond their elastic limit, such as handles and vehicle and implement parts.

#### COMPRESSION PARALLEL TO GRAIN.

In the compression parallel to grain test a 2 by 2 by 8 inch block is compressed in the direction of its length. Deformation is measured between two collars attached 6 inches apart to the specimen.

#### FIBER STRESS AT ELASTIC LIMIT.

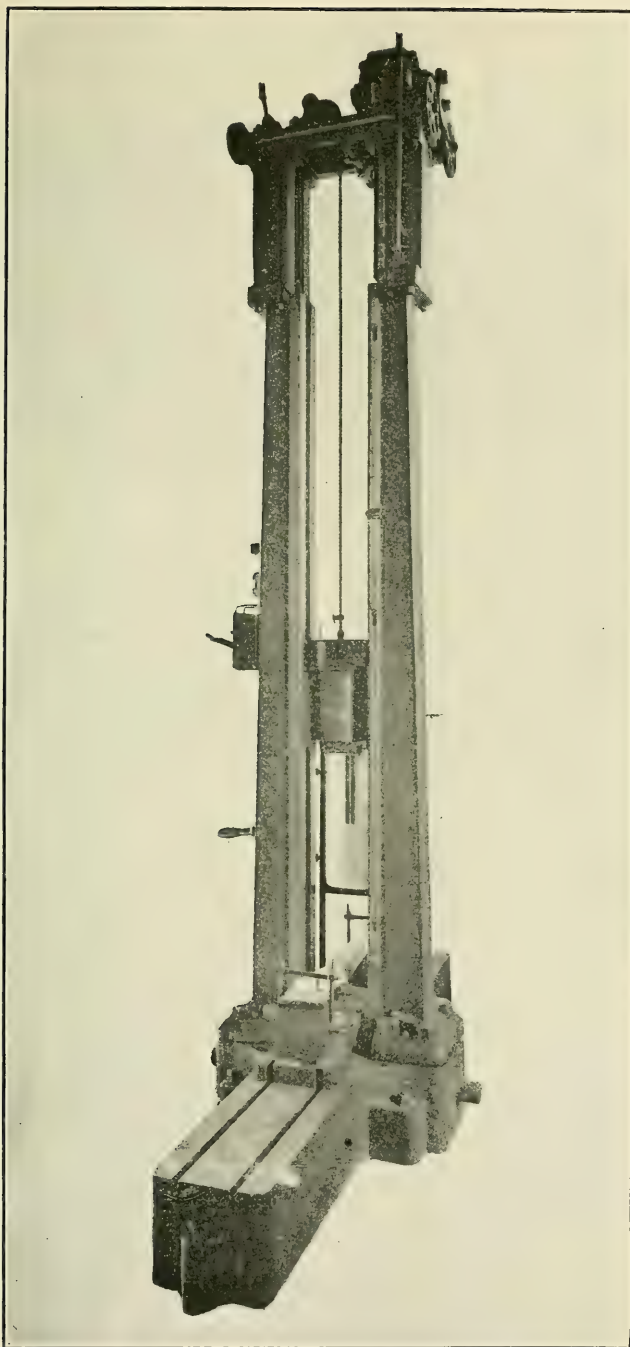
Fiber stress at elastic limit in compression parallel to the grain is not much used because in most cases it is more convenient to use maximum crushing strength, which is less variable and easier to obtain. The value is important in the derivation of safe working stresses for structural timber. (See also fiber stress at elastic limit, glossary, p. 21.)

#### MAXIMUM CRUSHING STRENGTH.

The maximum crushing strength is the maximum ability of a short block to sustain a slowly applied load. It is obtained by dividing the maximum load obtained in the test by the area of cross section of the block. This property is important in estimating the strength of columns.

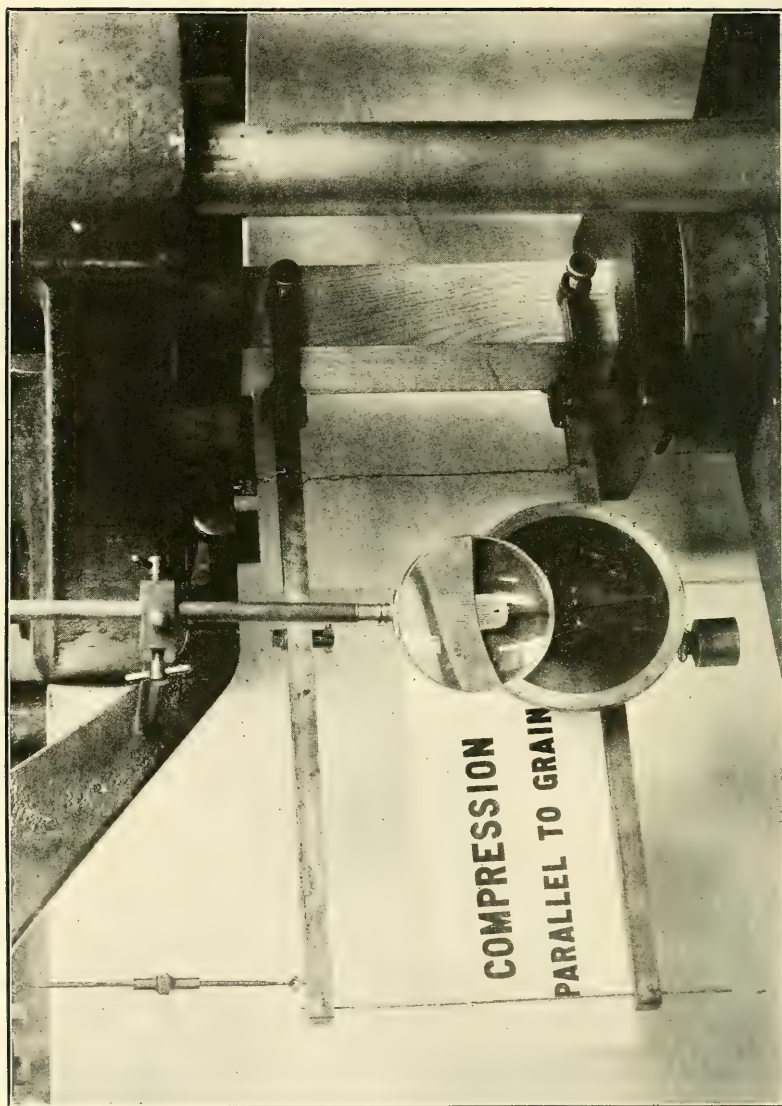
Tests of the crushing strength, because of their simplicity, are frequently the only tests used in studying the effect of various influences or processes on strength. Crushing strength is not necessarily representative of the other strength properties; consequently, when used alone, it will occasionally lead to erroneous conclusions. For instance, it was found that the crushing strength of some timbers was increased 10 per cent by a certain heat treatment. Other tests, however, revealed the fact that their resistance to shock had been reduced about 50 per cent.

A safe working stress for carefully selected structural timbers used as columns and in dry interior construction, all exceptionally light pieces excluded, is about one-third the crushing strength as given in the table for tests on green materials (Table 1). If the column is longer than about 10 times its least diameter, some formula should be used which will take care of the increased stress which would be caused by eccentric loading or by the bending of the column. (Such



IMPACT TESTING MACHINE.





COMPRESSION PARALLEL TO GRAIN TEST.

formulæ are discussed in the various textbooks on mechanics and strength of materials.)

#### COMPRESSION PERPENDICULAR TO GRAIN.

In the compression perpendicular to grain test, a block 2 by 2 inches in cross section and 6 inches long is laid upon its side and pressure applied to it through a cast-iron plate 2 inches wide laid across the center of the piece and at right angles to its length. Hence but one-third of the surface is directly subjected to compression.

The only strength value obtained in this test is the fiber stress at elastic limit. It represents the maximum stress which can be applied to the timber without injury. It is important in computing the bearing area for beams, stringers, joists, etc., and in comparing species for railroad ties.

Two-thirds of the fiber stress at elastic limit, as given in the table for tests on green material, may be used as a safe stress in dry interior construction.

#### HARDNESS.

Hardness is tested by measuring the load required to embed a 0.444-inch ball to one-half its diameter in the wood. This test is a modification of one originated by Janka.<sup>1</sup>

The hardness test is applied to end, radial, and tangential surfaces of the timber. There is no consistent difference between radial and tangential hardnesses and they are averaged and tabulated as "side hardness." End hardness is usually greater than side hardness. The quality represented by these figures is important in woods for paving blocks, railroad ties, furniture, flooring, etc.

#### SHEARING STRENGTH PARALLEL TO GRAIN.

The shearing test is made by applying force to a 2 by 2 inch lip projecting from the side of a block. The shearing stress is the maximum force required to shear off the projection divided by the area of the plane of failure.

Shearing strength parallel to the grain is a measure of the ability of timber to resist slipping of one part upon another along the grain. Shearing stress is produced to a greater or less degree in most uses of timber. It is most important in beams, where it is known as horizontal shear—the stress tending to cause the upper half of the beam to slide upon the lower. It is also important in the design of various kinds of timber joints.

Only about one-eighth of the values given in the table for green material (Table 1) should be used as allowable stress in horizontal

<sup>1</sup> "Die Härte des Holzes," by Gabriel Janka, k. k. Forst- und Domänenverwalter: Mitteilung der k. k. forstlichen Versuchsanstalt in Mariabrunn, Wien, 1906.

shear in beams. For small details, in timbers unaffected by shakes or checks, the allowable stress may be taken as one-fourth the value listed for green timber.

#### TENSION PERPENDICULAR TO GRAIN.

The tension perpendicular to grain tests are made on specimens 2 inches square and  $2\frac{1}{2}$  inches long, the tension area being 1 by 2 inches. The tension force is applied perpendicular to the grain. The values are of use in estimating the resistance of timber to the splitting actions of bolts and other fastenings. A factor of 5 should be applied to the values in Table 1 to get the allowable stress for design; i. e., one-fifth the values given in the tables.

#### EXPLANATION OF TABLE 3.

(See table on p. 45.)

The figures in Table 3 are presented as an aid to the interpretation of data given in Tables 1 and 2 and are explained as follows:

##### COLUMN 2.

The figures given in column 2 are to be applied to the data in Table 2. They are, of course, only approximate, as the exact variation of any property with change in moisture content is different for each species.<sup>1</sup> They will assist in rendering more nearly comparable data which are noncomparable because of differences of moisture.

Example: It is desired to compare the modulus of rupture of air-dry locust with that of air-dry bitternut hickory. The hickory has a modulus of rupture of 18,850 at 9.2 per cent moisture and the locust a modulus of rupture of 20,700 at 10 per cent moisture (see Table 2). According to Table 3, a 1 per cent change of moisture causes a 4 per cent change of modulus of rupture. Changing the hickory from 9.2 to 10 per cent moisture will decrease the strength by  $(10 - 9.2) \times 4$  per cent = 3.2 per cent; 3.2 per cent of 18,850 = 600. Then the moduli of rupture of black locust and bitternut hickory, when placed on a comparable basis, each being at 10 per cent moisture, are 20,700 and 18,250 pounds per square inch, respectively. The accuracy of this moisture reduction is greatest across small intervals. As the interval or difference of moisture increases the accuracy becomes less.

##### COLUMN 3.

Study of the data presented in this bulletin has shown that each of the shrinkage and strength properties of a given species can be estimated with fair accuracy from the average specific gravity, since each varies according to some power of the specific gravity.

<sup>1</sup> See Forest Service Bulletin 70 and Circular 108.



This power is given in column 3. Suppose, for example, it is desired to estimate the comparative strength in modulus of rupture and work to maximum load of a stick of timber whose specific gravity is known to be 25 per cent above the average. Since modulus of rupture varies as the first and work to maximum load as the second power of the specific gravity (see Table 3), it is probable that the modulus of rupture and work to maximum load are, respectively, about 125 and 156 per cent ( $1.56 = 1.25^2$ ) of the average values for the species.

## COLUMNS 4 AND 5.

The figures in columns 4 and 5 are derived from the original data on which the averages given in Table 1 are based, by the use of the processes usually employed to determine the accuracy of experimental data. They are not to be taken as too rigidly applicable to these averages (Table 1), but are a convenient approximate measure of the reliability of the averages and of the probability that an individual tree of a given species will be of average quality in any given property.

## COLUMN 4.

The probable error of the species average as given in this column is a measure of the reliability of the present averages and of the probable change in these averages by future tests. For example: The probable error in modulus of rupture is given as 4 per cent; this means that there is one chance in four that the present average modulus of rupture for a given species (if based on tests from five trees) is below 96 per cent ( $= 100 - 4$ ) of the true average, two chances in four that it is between 96 and 104 per cent of the true average. It follows that the two possibilities: (1) That the present average will be changed more than 4 per cent by future tests, and (2) that it will not be so changed, are equally probable. There is about one chance in 100 that the average will be changed by four times the probable error, or in this case 16 per cent.

The figures given apply to cases where five trees have been tested. When the number tested is other than five the probable variation can be obtained from the rule that the probable variation varies inversely as the square root of the number of trees tested. For instance, if 20 trees have been tested, the probable variation of the average modulus of rupture is  $\sqrt{\frac{5}{20}} \times 4$  per cent, or 2 per cent.

## COLUMN 5.

Column 5 gives the probable variation from the species average of the average of tests from an individual tree taken at random. For instance, the figure given for modulus of rupture is 9 per cent, which means that there is one chance in four that the modulus of rupture of a

tree taken at random will be below 91 per cent of the species average, one chance in four that it will be above 109 per cent, and two chances in four, or one chance in two, that it will be between 91 and 109 per cent of this average. There is also about one chance in 100 that the random tree will vary from the average an amount equal to four times the probable variation, or in this case 36 per cent.

## GLOSSARY.

### AIR DRY.

(See p. 7.)

Air-dry condition is the normal condition, with respect to moisture, of wood exposed to the air, although this condition may have been obtained by artificial means. The term "air dried" means dried by exposure to the air, while "kiln dried" indicates artificial drying.

Air dry is a very general term and may mean any degree of dryness from about 6 per cent moisture, as in furniture stock, to over 30 per cent moisture, as in timber dried to reduce its shipping weight. The degree of dryness in timber depends upon species, size, and the conditions under which the material is dried, especially such as humidity, method of piling, shelter, time of drying, etc. For instance, the wood of the conifers dries much more rapidly, on the average, than that of the hardwoods. Douglas fir bridge timbers will fall to about 30 per cent moisture in 2 years. Inch lumber of the same species, under the same conditions, will dry to 15 per cent moisture in considerably less time, and small-sized timber dried in a heated room will in some cases reach 6 per cent moisture. The same species, in the same sizes, piled in the same manner under shelter out of doors, will scarcely ever fall below 12 per cent moisture.

### DENSE.

Dense, as applied to wood, means compact, heavy (when dry), containing much wood substance in small space (see footnote, p. 5). For example, hickory is a very dense wood.

The oven-dry specific gravity is a measure of the density of wood. This figure is based on the weight, exclusive of moisture, but including rosin and other substances not volatile at 100° C.

### ELASTIC LIMIT.

(See pp. 13, 14, and 15.)

The elastic limit (sometimes called proportional limit) is that point where the distortion ceases to be in proportion to the load. For example, if a beam deflects one-sixteenth of an inch with a 50-pound load it will deflect one-eighth of an inch with 100 pounds, and so on, each additional load of 50 pounds causing an additional deflection of one-sixteenth of an inch until the "elastic limit" is reached,

after which the deflections increase more rapidly than the increase in load.

A timber stressed beyond the elastic limit will not resume its original form immediately upon the removal of the load.

#### ELASTICITY.

Elasticity is the property (possessed by most materials) of changing form with the application of force and recovering at once upon release from the force.

In any elastic material the amount of compression or deformation is proportional to the force applied.

Air and other gases under compression are elastic. The most commonly recognized elastic material is rubber. Timber is elastic within comparatively narrow limits.

The term "very elastic" as applied to wood is indefinite, because it may mean that the force required to produce a given deformation is great and the recovery sudden as in an ivory ball (see "Modulus of elasticity"); or that the amount of distortion to the elastic limit is great, as in a rubber ball, or that the wood possesses high elastic resilience, a combination of the two properties. (See "Elastic resilience" or "Work to the elastic limit.")

#### FIBER SATURATION POINT.

(See p. 11.)

Green wood usually contains water within the cell walls and "free" water in the pores. In drying, the water in the pores is the first to be evaporated. The fiber saturation point is that point at which no water exists in the pores of the timber but at which the cell walls are still saturated with moisture. The fiber saturation point varies with the species. The ordinary proportion of moisture—based on the dry weight of the wood—at the fiber saturation point is from 20 to 30 per cent.

#### FIBER STRESS AT ELASTIC LIMIT.

(See pp. 13, 15, and 16.)

Fiber stress at elastic limit is the stress obtained in a timber by loading it to its elastic limit. It is the greatest stress the timber will take under a given loading and immediately return to its former position.

#### FLEXIBILITY.

Flexibility is that quality which renders a material capable of being bent without breaking. Thus, green timber is more flexible than dry.

#### GREEN.

Green is the condition of timber as taken from the living tree.

Immediately upon being sawed from the tree lumber begins to lose moisture and otherwise change its condition. The rapidity of these changes is determined by the species, humidity, and circulation of air, heat, etc.



**MECHANICAL PROPERTIES.**

Mechanical properties are the properties of wood which enable it to resist deformations, loads, shocks, or forces. Thus the ability to resist shearing forces is a mechanical property of timber. (See "Strength.")

**MODULUS OF ELASTICITY.**

(See p. 14.)

Modulus of elasticity is the ratio of stress per unit area to corresponding strain per unit length, the distortion or strain being within the elastic limit.

Numerically, the modulus of elasticity of a material is the force in pounds required to stretch a sample of that material with a cross-sectional area of 1 square inch to double its length, on the assumption that the fibers would not be stressed beyond their elastic limit. India rubber has a very low modulus of elasticity, while that of steel is very high. It is, then, the measure of the stiffness or rigidity of a substance.

**MODULUS OF RUPTURE.**

(See p. 13.)

**PHYSICAL PROPERTIES.**

Physical properties, as the term is used in this bulletin, are those properties of wood which have to do with its structure, such as density, cell arrangements, fiber length, etc. In its broad sense the term physical properties includes all those properties listed as mechanical properties as well as those pertaining to its structure.

**RADIAL.**

Radial means extending outward from a center or an axis. Thus a radial surface in a tree is one extending from the pith of the tree outward, such as the wide faces of a quarter-sawed board.

**RINGS.**

(See p. 8.)

Rings are those circular markings around the center of a tree section which are produced by the contrast in density, hardness, color, etc., between springwood and summerwood. One ring, known as an annual ring, consists of a layer of springwood and a layer of summerwood.

**SHEAR.**

(See p. 17.)

Shear is the name of the stress which tends to keep two adjoining planes or surfaces of a body from sliding, one on the other, under the influence of two equal and parallel forces acting in opposite directions. A force which produces shear (or shearing stress) in a material is called a shearing force.

**SPRINGWOOD.**

The lighter and more porous layer of wood in the annual rings of a tree is known as the springwood or early wood. As the name implies, it is produced in spring growth, or in the earlier part of the growing season.

**STRAIN.**

The deformation or distortion produced by a stress or force is known as strain.

**STRENGTH.**

(See p. 6.)

The term "strength" as ordinarily used is a very indefinite one. It is usually thought of in connection with external loads or forces.

Strength in its broad sense is a measure of the mechanical properties, or of the ability of a timber to resist stress or deformation. Thus, strength in shear, strength as a beam, strength as a post, hardness, stiffness, toughness. These last three properties are not always thought of in connection with the term strength, but are unconsciously included whenever they are important in a specific use. See example of this as given on page 6.

Seldom, if ever, do any two species contain all the various properties in the same degree. This accounts for the special uses of the different species.

Much confusion often arises from comparing species for a special use on the basis of properties or strength values not of first importance in the specific instance.

**STRESS.**

Stress is distributed force.

Fiber stress is the distributed force tending to compress, tear apart, or change the relative position of the wood fibers.

Stress is measured by the force per unit area. Thus a short column 2 inches square (4 square inches) and supporting a load of 2,000 pounds will be under a stress or fiber stress of 500 pounds per square inch.

**SUMMERWOOD.**

(See p. 9.)

Summerwood is that denser layer of wood in the annual rings of a tree which is put on in summer or the latter part of the growing season.

**TANGENTIAL.**

Tangential, as applied in this publication, means tangent to or parallel to the curves of the annual rings in a cross section. Thus a tangential surface is a surface perpendicular to the radius of a tree.

## WORK.

(See p. 15.)

Work is the product of force and distance, or force acting through distance.

Work is essential in stopping bodies in motion, or in causing motion or change of motion of bodies.

Work is measured in inch-pounds, foot-pounds, etc.

An inch-pound is the work required to raise one pound 1 inch or to move a body 1 inch against a resistance of 1 pound.

## FORMULÆ USED IN COMPUTING.

## LEGEND.

A = Area of cross section; square inches.

B = Area under plate in compression-perpendicular-to-grain tests, square inches.

CS = Crushing strength, pounds per square inch.

E = Modulus of elasticity, pounds per square inch.

EL = Fiber stress at elastic limit, pounds per square inch.

J = Greatest calculated longitudinal shear, pounds per square inch.

K = Constant = 27.7 when weight is in pounds; 0.061 when weight is in grams.

MR = Modulus of rupture, pounds per square inch.

P = Maximum load, pounds.

P' = Load at elastic limit, pounds.

S = Dry specific gravity.

$\Delta$  = Total deflection or compression at elastic limit, inches.

b = Width, inches

d = Distance between centers of collars, inches.

h = Height, inches.

l = Span, inches (in compression parallel to grain l = length).

## BENDING.

Load applied at center:

$$J = \frac{0.75 \times P}{b \times h}$$

$$MR = \frac{1.5 \times P \times l}{b \times h^2}$$

$$EL = \frac{1.5 \times P' \times l}{b \times h^2}$$

$$E = \frac{P' \times l^3}{4 \times b \times h^3 \times \Delta}$$



Uniformly distributed load:

$$J = \frac{0.75 \times P}{b \times h}$$

$$MR = \frac{0.75 \times P \times l}{b \times h^2}$$

$$EL = \frac{0.75 \times P' \times l}{b \times h^2}$$

$$E = \frac{P' \times l^3}{6.4 \times b \times h^3 \times \Delta}$$

Any loading:

$$M = 1/6 F \times b \times h^2.$$

Where M = moment in inch-pounds either external or internal.

F = fiber stress for moment M.

$J = 3/2 \times \frac{V}{b \times h}$  where J = unit horizontal shear at any point and V = total vertical shear at that point.

#### COMPRESSION PARALLEL TO GRAIN.

$$CS = \frac{P}{A}$$

$$EL = \frac{P'}{A}$$

$$E = \frac{P' \times d}{A \times \Delta}$$

#### COMPRESSION PERPENDICULAR TO GRAIN.

$$EL = \frac{P'}{B}$$

#### SHEAR PARALLEL TO GRAIN.

$$\text{Shear} = \frac{P}{A}$$

#### SPECIFIC GRAVITY.

$$S = \frac{\text{weight} \times K}{\left(1 + \% \frac{\text{moisture}}{100}\right) \times \text{volume of piece in cubic inches}}$$

**TABLE 1.**

The data in Table 1 are derived from a considerably larger number of tests and are therefore somewhat more reliable than those of Table 2. Before an attempt is made to use these data, it is recommended that the entire text of this bulletin be read carefully, particularly "Misuse of terms," page 6. Attention should be given to "Precautions to be observed in the use of data," page 4, to the explanation of the column heads, pages 7 to 18, and to the discussion and illustrations of the use of the variability figures given in Table 3.

Where an apparent discrepancy is found between figures in this table and those in previous publications of the Forest Service, the data herein given may be considered as the most accurate (see p. 4).

Safe working stresses for the design of structural timbers should be based on the data in Table 1 rather than on those given in Table 2 for reasons presented elsewhere in this bulletin, particularly under "Data on air-dry timber," page 7, and "Static bending," page 12.

Safe working stresses will of necessity vary with the conditions under which the timber is used. Factors for obtaining working stresses for timber used in dry interior construction are given elsewhere in this bulletin as follows:

Columns—Under "Maximum crushing strength," page 16.

Details of joints—Under "Shearing strength parallel to grain," page 17, and under "Tension perpendicular to grain," page 18.

TABLE 1.—Results of tests on 126 species of wood tested in a green condition in the form of small clear pieces.

[Test specimens are 2 by 2 inches in section. Bending specimens are cut 30 inches long; others are shorter, depending on kind of test.]

| Common and botanical name. | Locality where grown.                           | Number of trees. | Number of rings per inch. | Summerwood (per cent). | Moisture content (per cent). | Specific gravity, oven-dry, based on— |                       | Weight per cubic foot (green) (pounds). | Shrinkage from green to oven-dry condition.    |                                             |                                                 | Static bending.                                         |                                              |                                                       |                                                |                                               |                                                             | Impact bending.                                                    |                                                         |                                                     | Compression parallel to grain. |     | Tension perpendicular to grain (pounds per square inch). | Shearing strength parallel to grain (pounds per square inch). | Compression perpendicular to grain—fiber stress at elastic limit (pounds per square inch). | Side (pounds). | End (pounds). | Hardness, load required to embed a 0.444-inch ball to one-half its diameter. |
|----------------------------|-------------------------------------------------|------------------|---------------------------|------------------------|------------------------------|---------------------------------------|-----------------------|-----------------------------------------|------------------------------------------------|---------------------------------------------|-------------------------------------------------|---------------------------------------------------------|----------------------------------------------|-------------------------------------------------------|------------------------------------------------|-----------------------------------------------|-------------------------------------------------------------|--------------------------------------------------------------------|---------------------------------------------------------|-----------------------------------------------------|--------------------------------|-----|----------------------------------------------------------|---------------------------------------------------------------|--------------------------------------------------------------------------------------------|----------------|---------------|------------------------------------------------------------------------------|
|                            |                                                 |                  |                           |                        |                              | Volume when green.                    | Volume when oven-dry. |                                         | In volume (per cent of dimensions when green). | Radial (per cent of dimensions when green). | Tangential (per cent of dimensions when green). | Fiber stress at elastic limit (pounds per square inch). | Modulus of rupture (pounds per square inch). | Modulus of elasticity (1,000 pounds per square inch). | To elastic limit (inch-pounds per cubic inch). | To maximum load (inch-pounds per cubic inch). | Work in bending—elastic limit (inch-pounds per cubic inch). | Height of drop causing complete failure, 50-pound hammer (inches). | Fiber stress at elastic limit (pounds per square inch). | Maximum crushing strength (pounds per square inch). |                                |     |                                                          |                                                               |                                                                                            |                |               |                                                                              |
| 1                          | 2                                               | 3                | 4                         | 5                      | 6                            | 7                                     | 8                     | 9                                       | 10                                             | 11                                          | 12                                              | 13                                                      | 14                                           | 15                                                    | 16                                             | 17                                            | 18                                                          | 19                                                                 | 20                                                      | 21                                                  | 22                             | 23  | 24                                                       | 25                                                            | 26                                                                                         | 27             |               |                                                                              |
| HARDWOODS.                 |                                                 |                  |                           |                        |                              |                                       |                       |                                         |                                                |                                             |                                                 |                                                         |                                              |                                                       |                                                |                                               |                                                             |                                                                    |                                                         |                                                     |                                |     |                                                          |                                                               |                                                                                            |                |               |                                                                              |
|                            | Alder, red ( <i>Alnus regina</i> ).             | 6                | 11                        | ....                   | 98                           | 0.37                                  | 0.43                  | 46                                      | 12.6                                           | 4.4                                         | 7.3                                             | 3,800                                                   | 6,500                                        | 1,170                                                 | 0.70                                           | 8.0                                           | 8,000                                                       | 2.6                                                                | 22                                                      | 2,650                                               | 2,960                          | 310 | 770                                                      | 390                                                           | 550                                                                                        | 440            |               |                                                                              |
|                            | Ash, bitmorean ( <i>Fraxinus biltmoreana</i> ). | 5                | 17                        | 49                     | 42                           | .51                                   | .58                   | 45                                      | 12.6                                           | 4.2                                         | 6.9                                             | 5,500                                                   | 9,300                                        | 1,340                                                 | 1.31                                           | 11.6                                          | 11,900                                                      | 4.9                                                                | 30                                                      | 3,560                                               | 3,980                          | 880 | 1,230                                                    | 540                                                           | 950                                                                                        | 850            |               |                                                                              |
|                            | Ash, black ( <i>Fraxinus nigra</i> ).           | 15               | 24                        | 53                     | 83                           | .46                                   | .53                   | 53                                      | 15.2                                           | 5.0                                         | 7.8                                             | 2,600                                                   | 6,000                                        | 1,020                                                 | .42                                            | 12.4                                          | 7,200                                                       | 2.5                                                                | 32                                                      | 1,620                                               | 2,290                          | 430 | 870                                                      | 490                                                           | 580                                                                                        | 550            |               |                                                                              |
|                            | Ash, blue ( <i>Fraxinus quadrangulata</i> ).    | 5                | 12                        | 49                     | 39                           | .53                                   | .60                   | 46                                      | 11.7                                           | 3.9                                         | 6.5                                             | 5,700                                                   | 9,600                                        | 1,240                                                 | 1.47                                           | 14.7                                          | 11,100                                                      | 5.0                                                                | 43                                                      | 3,540                                               | 4,180                          | 990 | 1,540                                                    | 580                                                           | 1,140                                                                                      | 1,030          |               |                                                                              |
|                            | Ash, green ( <i>Fraxinus lanceolata</i> ).      | 10               | 18                        | 58                     | 48                           | .52                                   | .61                   | 48                                      | 12.5                                           | 4.6                                         | 7.1                                             | 5,300                                                   | 9,500                                        | 1,400                                                 | 1.14                                           | 11.8                                          | 11,400                                                      | 5.0                                                                | 34                                                      | 3,560                                               | 4,200                          | 910 | 1,260                                                    | 590                                                           | 960                                                                                        | 870            |               |                                                                              |
|                            | Ash, Oregon ( <i>Fraxinus Oregona</i> ).        | 3                | 12                        | 63                     | 48                           | .50                                   | .58                   | 46                                      | 13.2                                           | 4.1                                         | 8.1                                             | 4,200                                                   | 7,600                                        | 1,130                                                 | .92                                            | 12.2                                          | 8,900                                                       | 3.0                                                                | 39                                                      | 2,740                                               | 3,510                          | 650 | 1,190                                                    | 490                                                           | 850                                                                                        | 790            |               |                                                                              |



TABLE 1.—*Results of tests on 126 species of wood tested in a green condition in the form of small clear pieces*—Continued.

| Common and botanical name.                      | Locality where grown.       | Number of trees. | Number of rings per inch. | Summerwood (per cent). | Moisture content (per cent). | Specific gravity oven-dry, based on— |                       | Weight per cubic foot (green) (pounds). | Shrinkage from green to oven-dry condition.    |                                             |                                                |                                                         | Static bending.                              |                                                       |                                                |                                               |                                                         |                                                      | Impact bending.                                                    |                                                         |                                                     |                                                                                            | Compression parallel to grain. |     | Tension perpendicular to grain (pounds per square inch). | Side (pounds). | End (pounds). | Hardness, load required to imbed a 0.444-inch ball to one-half its diameter. |
|-------------------------------------------------|-----------------------------|------------------|---------------------------|------------------------|------------------------------|--------------------------------------|-----------------------|-----------------------------------------|------------------------------------------------|---------------------------------------------|------------------------------------------------|---------------------------------------------------------|----------------------------------------------|-------------------------------------------------------|------------------------------------------------|-----------------------------------------------|---------------------------------------------------------|------------------------------------------------------|--------------------------------------------------------------------|---------------------------------------------------------|-----------------------------------------------------|--------------------------------------------------------------------------------------------|--------------------------------|-----|----------------------------------------------------------|----------------|---------------|------------------------------------------------------------------------------|
|                                                 |                             |                  |                           |                        |                              | Volume when green.                   | Volume when oven-dry. |                                         | In volume (per cent of dimensions when green). | Radial (per cent of dimensions when green). | Tangential (percent of dimensions when green). | Fiber stress at elastic limit (pounds per square inch). | Modulus of rupture (pounds per square inch). | Modulus of elasticity (1,000 pounds per square inch). | To elastic limit (inch-pounds per cubic inch). | To maximum load (inch-pounds per cubic inch). | Fiber stress at elastic limit (pounds per square inch). | Work in bending to elastic limit (inch-square inch). | Height of drop causing complete failure, 50-pound hammer (inches). | Fiber stress at elastic limit (pounds per square inch). | Maximum crushing strength (pounds per square inch). | Compression perpendicular to grain—fiber stress at elastic limit (pounds per square inch). |                                |     |                                                          |                |               |                                                                              |
| 1                                               | 2                           | 3                | 4                         | 5                      | 6                            | 7                                    | 8                     | 9                                       | 10                                             | 11                                          | 12                                             | 13                                                      | 14                                           | 15                                                    | 16                                             | 17                                            | 18                                                      | 19                                                   | 20                                                                 | 21                                                      | 22                                                  | 23                                                                                         | 24                             | 25  | 26                                                       | 27             |               |                                                                              |
| HARDWOODS—contd.                                |                             |                  |                           |                        |                              |                                      |                       |                                         |                                                |                                             |                                                |                                                         |                                              |                                                       |                                                |                                               |                                                         |                                                      |                                                                    |                                                         |                                                     |                                                                                            |                                |     |                                                          |                |               |                                                                              |
| Ash, pumpkin (Fraxinus profunda).               | Missouri.....               | 3                | 21                        | 46                     | 51                           | 0.48                                 | 0.55                  | 46                                      | 12.0                                           | 3.7                                         | 6.3                                            | 4,500                                                   | 7,600                                        | 1,040                                                 | 1.08                                           | 9.4                                           | 8,800                                                   | 3.7                                                  | 31                                                                 | 2,830                                                   | 3,360                                               | 930                                                                                        | 1,210                          | 570 | 880                                                      | 750            |               |                                                                              |
| Ash, white (forest grown).                      | Arkansas, West Virginia.    | 10               | 16                        | 50                     | 43                           | .52                                  | .60                   | 46                                      | 12.6                                           | 4.2                                         | 6.5                                            | 4,900                                                   | 9,100                                        | 1,350                                                 | 1.03                                           | 13.4                                          | 11,700                                                  | 5.0                                                  | 36                                                                 | 3,230                                                   | 3,800                                               | 800                                                                                        | 1,260                          | 620 | 1,000                                                    | 900            |               |                                                                              |
| Ash, white (second growth).                     | New York.....               | 5                | 9                         | 63                     | 40                           | .58                                  | .71                   | 51                                      | 14.0                                           | 5.3                                         | 8.7                                            | 6,100                                                   | 10,800                                       | 1,640                                                 | 1.30                                           | 16.3                                          | 13,800                                                  | 5.9                                                  | 47                                                                 | 3,820                                                   | 4,610                                               | 790                                                                                        | 1,600                          | 790 | 1,140                                                    | 1,080          |               |                                                                              |
| Aspen (Populus tremu-<br>loides).               | Wisconsin.....              | 5                | 8                         | .....                  | 107                          | .36                                  | .42                   | 47                                      | 11.1                                           | 3.3                                         | 6.9                                            | 2,900                                                   | 5,300                                        | 840                                                   | .65                                            | 6.9                                           | 6,900                                                   | 2.5                                                  | 28                                                                 | 1,620                                                   | 2,160                                               | 200                                                                                        | 620                            | 180 | 270                                                      | 320            |               |                                                                              |
| Aspen, largetooth (Pop-<br>ulus grandidentata). | .....do.....                | 5                | 8                         | .....                  | 96                           | .35                                  | .41                   | 43                                      | 11.6                                           | 3.1                                         | 7.9                                            | 3,200                                                   | 5,800                                        | 1,180                                                 | .50                                            | 6.1                                           | 7,600                                                   | 2.7                                                  | 18                                                                 | 2,130                                                   | 2,720                                               | 270                                                                                        | 810                            | 390 | 440                                                      | 370            |               |                                                                              |
| Basswood (Tilia ameri-<br>cana).                | Pennsylvania,<br>Wisconsin. | 8                | 19                        | 29                     | 103                          | .33                                  | .40                   | 41                                      | 15.8                                           | 6.6                                         | 9.3                                            | 2,700                                                   | 5,000                                        | 1,030                                                 | .42                                            | 5.2                                           | 6,200                                                   | 2.0                                                  | 17                                                                 | 1,710                                                   | 2,210                                               | 210                                                                                        | 610                            | 280 | 280                                                      | 250            |               |                                                                              |
| Beech (Fagus atropu-<br>nicea).                 | Indiana, Pennsyl-<br>vania. | 10               | 19                        | 30                     | 62                           | .54                                  | .66                   | 55                                      | 16.2                                           | 4.8                                         | 10.6                                           | 4,500                                                   | 8,200                                        | 1,240                                                 | .99                                            | 12.5                                          | 10,400                                                  | 4.2                                                  | 40                                                                 | 2,550                                                   | 3,280                                               | 610                                                                                        | 1,210                          | 760 | 950                                                      | 820            |               |                                                                              |
| Birch, paper (Betula<br>papyrifera).            | Wisconsin.....              | 5                | 6                         | 36                     | 72                           | .47                                  | .60                   | 51                                      | 16.3                                           | 6.6                                         | 8.8                                            | 2,900                                                   | 5,800                                        | 1,010                                                 | .49                                            | 15.0                                          | 7,800                                                   | 2.7                                                  | 45                                                                 | 1,650                                                   | 2,210                                               | 300                                                                                        | 790                            | 380 | 400                                                      | 490            |               |                                                                              |

|                                                              |                              |    |       |       |     |     |       |    |       |       |       |       |        |       |      |      |        |       |       |       |        |       |       |       |       |       |
|--------------------------------------------------------------|------------------------------|----|-------|-------|-----|-----|-------|----|-------|-------|-------|-------|--------|-------|------|------|--------|-------|-------|-------|--------|-------|-------|-------|-------|-------|
| Birch, sweet ( <i>Betula lenta</i> ).....                    | Pennsylvania.....            | 51 | 27    | ..... | 61  | .59 | .70   | 59 | 15.0  | 6.3   | 7.6   | 4,500 | 8,600  | 1,490 | .81  | 15.6 | 9,500  | 3.1   | 44    | 2,650 | 3,560  | 520   | 1,220 | 550   | 1,020 | 803   |
| Birch, yellow ( <i>Betula lutea</i> ).....                   | Pennsylvania, Wisconsin..... | 10 | 19    | 26    | 68  | .54 | .66   | 58 | 16.8  | 7.4   | 9.0   | 4,600 | 8,600  | 1,540 | .80  | 16.6 | 11,700 | 4.5   | 40    | 2,760 | 3,460  | 450   | 1,110 | 480   | 820   | 740   |
| Buckeye, yellow ( <i>Esculus octandra</i> ).....             | Tennessee.....               | 5  | 15    | ..... | 141 | .33 | .38   | 49 | 12.0  | 3.5   | 7.8   | 2,600 | 4,800  | 980   | .41  | 5.4  | 6,500  | 2.1   | 18    | 1,640 | 2,050  | 210   | 660   | 320   | 360   | 290   |
| Buckeye, white ( <i>Esculus glabra</i> ).....                | Oregon.....                  | 5  | 17    | ..... | 61  | .50 | .55   | 50 | 7.6   | 3.2   | 4.6   | 3,400 | 6,300  | 630   | 1.04 | 13.4 | 8,700  | 3.6   | 58    | 1,880 | 3,270  | 670   | 1,150 | 510   | 680   | 730   |
| Burk horn, caskara ( <i>Rhamnus purshiana</i> ).....         | Tennessee, Wisconsin.....    | 10 | 9     | ..... | 104 | .36 | .40   | 46 | 10.2  | 3.3   | 6.1   | 2,900 | 5,400  | 970   | .52  | 8.2  | 7,300  | 2.5   | 24    | 1,960 | 2,420  | 270   | 760   | 430   | 410   | 390   |
| Cherry, black ( <i>Prunus serotina</i> ).....                | Pennsylvania.....            | 5  | 11    | ..... | 55  | .47 | .53   | 46 | 11.5  | 3.7   | 7.1   | 4,200 | 8,000  | 1,310 | .80  | 12.8 | 10,200 | 4.1   | 33    | 2,940 | 3,540  | 440   | 1,130 | 570   | 750   | 600   |
| Cherry, wild red ( <i>Prunus pennsylvanica</i> ).....        | Tennessee.....               | 5  | 6     | ..... | 46  | .36 | .42   | 33 | 12.8  | 2.8   | 10.3  | 2,900 | 5,000  | 1,040 | .47  | 6.2  | 6,600  | 2.1   | 22    | 1,830 | 2,170  | 260   | 680   | 300   | 440   | 390   |
| Chestnut ( <i>Castanea dentata</i> ).....                    | Maryland, Tennessee.....     | 10 | 10    | 48    | 122 | .40 | .46   | 55 | 11.6  | 3.4   | 6.7   | 3,100 | 5,600  | 930   | .59  | 7.0  | 7,900  | 2.8   | 24    | 2,040 | 2,470  | 380   | 800   | 430   | 530   | 420   |
| Chinquapin, western ( <i>Castanopsis chrysophylla</i> )..... | Oregon.....                  | 5  | 15    | ..... | 134 | .42 | .48   | 61 | 13.2  | 4.6   | 7.4   | 4,200 | 7,000  | 1,020 | 1.09 | 9.5  | 8,800  | 3.4   | 31    | 1,920 | 3,020  | 490   | 1,010 | 480   | 730   | 600   |
| Cottonwood ( <i>Populus deltoides</i> ).....                 | Missouri.....                | 5  | 6     | ..... | 111 | .37 | .43   | 49 | 14.1  | 3.9   | 9.2   | 2,900 | 5,300  | 1,010 | .49  | 7.3  | 7,200  | 2.3   | 21    | 1,770 | 2,280  | 240   | 680   | 410   | 380   | 340   |
| Cottonwood, black ( <i>Populus trichocarpa</i> ).....        | Washington.....              | 5  | 6     | ..... | 132 | .32 | .37   | 46 | 12.4  | 3.6   | 8.6   | 2,900 | 4,800  | 1,070 | .44  | 5.0  | 6,800  | 2.2   | 20    | 1,770 | 2,160  | 200   | 600   | 270   | 280   | 250   |
| Cucumber tree ( <i>Magnolia acuminata</i> ).....             | Tennessee.....               | 5  | 14    | ..... | 80  | .44 | .52   | 50 | 13.6  | 5.2   | 8.8   | 4,200 | 7,400  | 1,560 | .66  | 10.0 | 9,300  | 2.9   | 30    | 2,760 | 3,140  | 410   | 990   | 440   | 600   | 520   |
| Dogwood (flowering) ( <i>Cornus florida</i> ).....           | do.....                      | 5  | 24    | ..... | 62  | .64 | .80   | 65 | 19.9  | 7.1   | 11.3  | 4,800 | 8,800  | 1,180 | 1.11 | 21.0 | 7,100  | 3.5   | 58    | ..... | 3,640  | 1,030 | 1,520 | ..... | 1,410 | 1,410 |
| Dogwood, western ( <i>Cornus florida</i> ).....              | Oregon.....                  | 5  | 21    | ..... | 52  | .58 | .70   | 55 | 17.2  | 6.4   | 9.6   | 4,200 | 8,200  | 1,090 | .92  | 17.0 | 9,800  | 3.6   | 56    | 2,280 | 3,640  | 870   | 1,300 | 740   | 1,140 | 980   |
| Elder, pale ( <i>Sambucus nigra</i> ).....                   | do.....                      | 5  | 6     | ..... | 124 | .46 | .57   | 65 | 15.6  | 4.4   | 9.0   | 3,400 | 6,600  | 900   | .72  | 8.8  | 8,000  | 2.9   | 38    | 2,450 | 3,040  | 520   | 1,090 | 560   | 760   | 720   |
| Elm, cork ( <i>Ulmus racemosa</i> ).....                     | Wisconsin.....               | 10 | 28    | 50    | 50  | .58 | .66   | 54 | 14.1  | 4.8   | 8.1   | 4,600 | 9,500  | 1,190 | 1.20 | 19.8 | 11,000 | 4.1   | 50    | 2,870 | 3,780  | 750   | 1,270 | 660   | 980   | 990   |
| Elm, slippery ( <i>Ulmus pubescens</i> ).....                | Indiana, Wisconsin.....      | 6  | 16    | 54    | 85  | .48 | .56   | 56 | 13.8  | 4.9   | 8.9   | 4,000 | 8,000  | 1,230 | .82  | 15.4 | 9,200  | 3.4   | 47    | 2,840 | 3,320  | 510   | 1,110 | 650   | 750   | 660   |
| Elm, white ( <i>Ulmus americana</i> ).....                   | Wisconsin, Pennsylvania..... | 6  | 18    | 31    | 88  | .44 | .54   | 52 | 14.4  | 4.2   | 9.5   | 3,600 | 6,900  | 1,030 | .83  | 11.0 | 8,100  | 2.9   | 34    | 2,290 | 2,880  | 390   | 920   | 560   | 610   | 550   |
| Gum, black ( <i>Nyssa sylvatica</i> ).....                   | Tennessee.....               | 5  | 27    | ..... | 55  | .46 | .55   | 45 | 13.9  | 4.4   | 7.7   | 4,000 | 7,000  | 1,030 | .91  | 8.0  | 9,800  | 4.0   | 30    | 2,440 | 3,040  | 600   | 1,100 | 570   | 790   | 640   |
| Gum, blue ( <i>Picea canadensis</i> ).....                   | California.....              | 5  | ..... | ..... | 79  | .62 | .80   | 70 | 22.5  | 7.6   | 15.3  | 7,600 | 11,200 | 2,010 | 1.65 | 13.9 | 14,200 | 4.7   | 40    | 4,870 | 5,250  | 1,020 | 1,550 | 640   | 1,310 | 1,340 |
| Gum, cotton ( <i>Nyssa aquatica</i> ).....                   | Louisiana.....               | 6  | 10    | 26    | 97  | .46 | .52   | 56 | 12.5  | 4.2   | 7.6   | 4,200 | 7,300  | 1,050 | .98  | 8.3  | 9,000  | 3.3   | 30    | 2,760 | 3,370  | 590   | 1,190 | 600   | 800   | 710   |
| Gum, red ( <i>Liquidambar styraciflua</i> ).....             | Missouri.....                | 10 | 16    | ..... | 81  | .44 | .53   | 50 | 15.0  | 5.2   | 9.9   | 3,700 | 6,800  | 1,150 | .81  | 9.4  | 10,000 | 3.9   | 33    | 2,360 | 2,840  | 460   | 1,070 | 510   | 630   | 520   |
| Hackberry ( <i>Celtis occidentalis</i> ).....                | Indiana, Wisconsin.....      | 6  | 12    | 56    | 65  | .48 | .56   | 50 | 13.8  | 4.8   | 8.9   | 2,900 | 6,500  | 950   | .58  | 14.5 | 7,900  | 3.1   | 48    | 2,060 | 2,650  | 490   | 1,070 | 630   | 760   | 690   |
| Haw, pear ( <i>Crataegus tomentosa</i> ).....                | Wisconsin.....               | 2  | 11    | ..... | 63  | .62 | ..... | 63 | ..... | ..... | ..... | 3,900 | 7,600  | 960   | .89  | 22.7 | .....  | ..... | ..... | ..... | .....  | 980   | 1,360 | ..... | 1,220 | 1,200 |
| Hickory, big shellbark ( <i>Hicoria laciniosa</i> ).....     | Mississippi, Ohio.....       | 19 | 19    | 65    | 61  | .62 | ..... | 63 | 19.2  | 7.6   | 12.6  | 5,600 | 10,500 | 1,340 | 1.36 | 29.9 | 14,200 | 7.0   | 104   | 2,740 | 43,920 | 1,000 | 1,190 | ..... | ..... | ..... |

TABLE 1.—Results of tests on 126 species of wood tested in a green condition in the form of small clear pieces—Continued.

| Common and botanical name.                 | Locality where grown.                                   | Number of trees. | Number of rings per inch. | Summerwood (per cent). | Moisture content (per cent). | Specific gravity oven dry, based on— |                       | Weight per cubic foot (green) (pounds). | Shrinkage from green to oven-dry condition.    |                                             |                                                 | Static bending.                                         |                                              |                                                       |                                             | Impact bending.                                      |                                                         |                                                                    |                                                         | Compression parallel to grain.                      |       | Tension perpendicular to grain (pounds per square inch). | Shearing strength parallel to grain (pounds per square inch). | Compression perpendicular to grain—fiber stress at elastic limit (pounds per square inch). | Side (pounds). | End (pounds). | Hardness, load required to imbed a 0.444-inch ball to one-half its diameter. |
|--------------------------------------------|---------------------------------------------------------|------------------|---------------------------|------------------------|------------------------------|--------------------------------------|-----------------------|-----------------------------------------|------------------------------------------------|---------------------------------------------|-------------------------------------------------|---------------------------------------------------------|----------------------------------------------|-------------------------------------------------------|---------------------------------------------|------------------------------------------------------|---------------------------------------------------------|--------------------------------------------------------------------|---------------------------------------------------------|-----------------------------------------------------|-------|----------------------------------------------------------|---------------------------------------------------------------|--------------------------------------------------------------------------------------------|----------------|---------------|------------------------------------------------------------------------------|
|                                            |                                                         |                  |                           |                        |                              | Volume when green.                   | Volume when oven-dry. |                                         | In volume (per cent of dimensions when green). | Radial (per cent of dimensions when green). | Tangential (per cent of dimensions when green). | Fiber stress at elastic limit (pounds per square inch). | Modulus of rupture (pounds per square inch). | Modulus of elasticity (1,000 pounds per square inch). | Work in bending—inch-pounds per cubic inch. | Work in bending to elastic limit (inch-square inch). | Fiber stress at elastic limit (pounds per square inch). | Height of drop causing complete failure, 50-pound hammer (inches). | Fiber stress at elastic limit (pounds per square inch). | Maximum crushing strength (pounds per square inch). |       |                                                          |                                                               |                                                                                            |                |               |                                                                              |
| 1                                          | 2                                                       | 3                | 4                         | 5                      | 6                            | 7                                    | 8                     | 9                                       | 10                                             | 11                                          | 12                                              | 13                                                      | 14                                           | 15                                                    | 16                                          | 17                                                   | 18                                                      | 19                                                                 | 20                                                      | 21                                                  | 22    | 23                                                       | 24                                                            | 25                                                                                         | 26             | 27            |                                                                              |
| HARDWOODS—con'd.                           |                                                         |                  |                           |                        |                              |                                      |                       |                                         |                                                |                                             |                                                 |                                                         |                                              |                                                       |                                             |                                                      |                                                         |                                                                    |                                                         |                                                     |       |                                                          |                                                               |                                                                                            |                |               |                                                                              |
| Hickory, bitternut (Hicoria minima).       | Ohio.....                                               | 11               | 11                        | 70                     | 66                           | 0.60                                 | ...                   | 63                                      | ...                                            | ...                                         | ...                                             | 5,500                                                   | 10,300                                       | 1,400                                                 | 1.22                                        | 20.0                                                 | 15,900                                                  | 8.5                                                                | 66                                                      | 4,330                                               | 4,570 | 990                                                      | 1,240                                                         | ...                                                                                        | ...            | ...           |                                                                              |
| Hickory, mockernut (Hicoria alba).         | West Virginia, Mississippi, Pennsylvania, Missouri..... | 20               | 18                        | 63                     | 59                           | .64                                  | ...                   | 64                                      | 17.9                                           | 7.8                                         | 11.0                                            | 6,300                                                   | 11,100                                       | 1,570                                                 | 1.38                                        | 26.1                                                 | 15,100                                                  | 6.7                                                                | 88                                                      | 3,900                                               | 4,480 | 1,000                                                    | 1,280                                                         | ...                                                                                        | ...            | ...           |                                                                              |
| Hickory, nutmeg (Hicoria myristicæformis). | Mississippi.....                                        | 5                | 22                        | 59                     | 74                           | .56                                  | ...                   | 61                                      | ...                                            | ...                                         | ...                                             | 4,900                                                   | 9,100                                        | 1,260                                                 | 1.06                                        | 22.8                                                 | 12,800                                                  | 6.1                                                                | 54                                                      | 3,620                                               | 3,980 | 940                                                      | 1,030                                                         | ...                                                                                        | ...            | ...           |                                                                              |
| Hickory, pecan (Hicoria pecan).            | Missouri.....                                           | 5                | 12                        | 63                     | 63                           | .60                                  | 0.69                  | 61                                      | 13.6                                           | 4.9                                         | 8.9                                             | 5,200                                                   | 9,800                                        | 1,370                                                 | 1.18                                        | 14.6                                                 | 12,300                                                  | 5.0                                                                | 53                                                      | 3,040                                               | 3,990 | 960                                                      | 1,480                                                         | 680                                                                                        | 1,270          | 1,310         |                                                                              |
| Hickory, pignut (Hicoria glabra).          | Ohio, Mississippi, Pennsylvania, West Virginia, do..... | 60               | 20                        | 65                     | 54                           | .66                                  | ...                   | 64                                      | 17.9                                           | 7.2                                         | 11.5                                            | 6,200                                                   | 11,700                                       | 1,650                                                 | 1.34                                        | 31.7                                                 | 16,900                                                  | 8.8                                                                | 89                                                      | 3,950                                               | 4,810 | 1,140                                                    | 1,370                                                         | ...                                                                                        | ...            | ...           |                                                                              |
| Hickory, shagbark (Hicoria ovata).         | West Virginia, do.....                                  | 24               | 19                        | 66                     | 60                           | .64                                  | ...                   | 64                                      | 16.7                                           | 7.0                                         | 10.5                                            | 5,900                                                   | 11,000                                       | 1,570                                                 | 1.28                                        | 23.7                                                 | 14,400                                                  | 6.4                                                                | 74                                                      | 3,430                                               | 4,580 | 1,000                                                    | 1,320                                                         | ...                                                                                        | ...            | ...           |                                                                              |
| Hickory, water (Hicoria aquatica).         | Mississippi.....                                        | 2                | 15                        | 67                     | 80                           | .61                                  | ...                   | 69                                      | ...                                            | ...                                         | ...                                             | 6,000                                                   | 10,700                                       | 1,560                                                 | 1.29                                        | 18.8                                                 | 13,700                                                  | 6.1                                                                | 56                                                      | 3,240                                               | 4,660 | 1,090                                                    | 1,440                                                         | ...                                                                                        | ...            | ...           |                                                                              |



|                                                |                                          |    |    |     |     |     |     |    |      |     |      |       |        |       |      |      |        |     |    |       |       |       |       |      |       |       |
|------------------------------------------------|------------------------------------------|----|----|-----|-----|-----|-----|----|------|-----|------|-------|--------|-------|------|------|--------|-----|----|-------|-------|-------|-------|------|-------|-------|
| Holly, American (Ilex opaca).                  | Tennessee.                               | 5  | 27 | ... | 82  | .50 | .61 | 57 | 16.2 | 4.5 | 9.5  | 3,400 | 6,500  | 900   | .72  | 10.8 | 8,900  | 4.4 | 51 | 1,970 | 2,640 | 610   | 1,130 | 610  | 860   | 790   |
| Hornbeam (Ostrya virginiana).                  | Wisconsin.                               | 5  | 29 | ... | 52  | .63 | .76 | 60 | 18.6 | 8.2 | 9.6  | 4,500 | 8,500  | 1,150 | 1.02 | 13.3 | 10,600 | 3.5 | 73 | 2,620 | 3,570 | 730   | 1,370 | 450  | 1,160 | 1,170 |
| Laurel, California (Umbellularia californica). | Oregon.                                  | 5  | 6  | ... | 70  | .51 | .59 | 55 | 11.9 | 2.8 | 8.1  | 3,900 | 6,600  | 720   | 1.23 | 16.8 | 8,300  | 4.1 | 57 | 1,960 | 3,020 | 800   | 1,270 | 780  | 1,020 | 1,000 |
| Laurel, mountain (Kalmia latifolia).           | Tennessee.                               | 5  | 24 | ... | 62  | .62 | .74 | 62 | 14.4 | 5.6 | 8.8  | 5,800 | 8,400  | 920   | 2.03 | 12.5 | 10,200 | 5.2 | 32 | ..... | 4,310 | 1,110 | 1,670 | .... | 1,400 | 1,300 |
| Locust, black (Robinia pseudacacia).           | .....do.                                 | 3  | 11 | 51  | 40  | .66 | .71 | 58 | 9.8  | 4.4 | 6.9  | 8,800 | 13,800 | 1,850 | 2.36 | 15.4 | 18,300 | 7.9 | 44 | 6,280 | 6,800 | 1,430 | 1,760 | 770  | 1,640 | 1,570 |
| Locust, honey (Gleditsia triacanthos).         | Missouri, Indiana.                       | 6  | 9  | 45  | 63  | .60 | .67 | 61 | 10.8 | 4.2 | 6.6  | 5,600 | 10,200 | 1,290 | 1.40 | 12.6 | 11,800 | 4.6 | 47 | 3,320 | 4,420 | 1,420 | 1,660 | 930  | 1,440 | 1,390 |
| Madrona (Arbutus menziesii).                   | California, Oregon.                      | 6  | 10 | ... | 68  | .57 | .69 | 60 | 17.4 | 5.4 | 11.9 | 4,700 | 7,600  | 880   | 1.43 | 11.2 | 10,200 | 4.7 | 40 | 2,340 | 3,320 | 780   | 1,420 | 770  | 1,120 | 940   |
| Magnolia (evergreen) (Magnolia foetida).       | Louisiana.                               | 2  | 15 | ... | 117 | .46 | .53 | 62 | 12.3 | 5.4 | 6.6  | 3,600 | 6,800  | 1,110 | .67  | 15.4 | 8,800  | 3.2 | 54 | 2,200 | 2,700 | 570   | 1,040 | 610  | 780   | 740   |
| Maple, Oregon (Acer macrophyllum).             | Washington.                              | 5  | 12 | ... | 72  | .44 | .51 | 47 | 11.6 | 3.7 | 7.1  | 4,400 | 7,400  | 1,100 | 1.02 | 8.7  | 8,500  | 2.8 | 23 | 2,380 | 3,240 | 550   | 1,110 | 600  | 760   | 620   |
| Maple, red (Acer rubrum).                      | Pennsylvania, Wisconsin.                 | 9  | 16 | 24  | 70  | .48 | .54 | 51 | 12.5 | 3.8 | 8.1  | 4,100 | 7,800  | 1,420 | .60  | 10.6 | 9,900  | 3.7 | 30 | 2,500 | 3,350 | 520   | 1,080 | 580  | 740   | 600   |
| Maple, silver (Acer saccharum).                | Wisconsin.                               | 5  | 7  | ... | 66  | .44 | .51 | 46 | 12.0 | 3.0 | 7.2  | 3,100 | 5,800  | 940   | .61  | 11.0 | 6,800  | 2.6 | 29 | 1,950 | 2,490 | 460   | 1,050 | 560  | 670   | 590   |
| Maple, sugar (Acer saccharum).                 | Indiana, Pennsylvania, Wisconsin.        | 17 | 21 | 49  | 60  | .56 | .66 | 56 | 14.5 | 4.8 | 9.2  | 5,000 | 9,100  | 1,480 | 1.08 | 11.9 | 12,100 | 5.0 | 36 | 3,120 | 3,860 | 750   | 1,380 | 770  | 1,000 | 910   |
| Oak, bur (Quercus macrocarpa).                 | Wisconsin.                               | 5  | 12 | 59  | 70  | .58 | .67 | 61 | 12.7 | 4.4 | 8.8  | 3,600 | 7,200  | 880   | .89  | 10.7 | 10,000 | 4.7 | 44 | 2,310 | 3,290 | 840   | 1,350 | 800  | 1,160 | 1,110 |
| Oak, California black (Quercus californica).   | California, Oregon.                      | 10 | 16 | 52  | 106 | .51 | .58 | 66 | 12.1 | 3.6 | 6.6  | 3,400 | 6,200  | 740   | 1.03 | 8.8  | 8,200  | 3.4 | 30 | 1,880 | 2,800 | 890   | 1,140 | 700  | 910   | 850   |
| Oak, canyon live (Quercus chrysolepis).        | California.                              | 3  | 13 | ... | 62  | .70 | .84 | 71 | 16.2 | 8.0 | 14.3 | 6,300 | 10,600 | 1,340 | 1.70 | 14.4 | 11,200 | 3.9 | 47 | 4,050 | 4,690 | 1,480 | 1,700 | 970  | 1,590 | 1,570 |
| Oak, chestnut (Quercus prinus).                | Tennessee.                               | 5  | 23 | 50  | 72  | .57 | .67 | 62 | 16.7 | 5.5 | 9.7  | 4,600 | 8,000  | 1,370 | .90  | 9.4  | 12,000 | 4.6 | 35 | 2,890 | 3,620 | 660   | 1,210 | 690  | 970   | 890   |
| Oak, cow (Quercus michauxii).                  | Louisiana.                               | 4  | 12 | 58  | 76  | .60 | .76 | 65 | 19.4 | 5.9 | 9.2  | 4,800 | 8,500  | 1,350 | 1.00 | 12.8 | 10,400 | 3.2 | 45 | 3,060 | 3,540 | 710   | 1,260 | 670  | 1,100 | 1,110 |
| Oak, laurel (Quercus laurifolia).              | .....do.                                 | 5  | 11 | 61  | 84  | .56 | .70 | 64 | 19.0 | 3.9 | 9.5  | 4,500 | 7,900  | 1,390 | .86  | 11.2 | 10,400 | 3.4 | 39 | 2,730 | 3,170 | 710   | 1,180 | 770  | 1,020 | 1,000 |
| Oak, Pacific post (Quercus garryana).          | Oregon.                                  | 10 | 16 | 49  | 72  | .64 | .75 | 69 | 13.4 | 4.2 | 9.0  | 4,600 | 7,700  | 790   | 1.51 | 13.7 | 10,300 | 4.8 | 49 | 2,510 | 3,570 | 1,380 | 1,630 | 940  | 1,430 | 1,390 |
| Oak, post (Quercus minor).                     | Arkansas, Louisiana.                     | 10 | 26 | 54  | 69  | .60 | .74 | 63 | 16.2 | 5.4 | 9.8  | 5,000 | 8,100  | 1,090 | 1.31 | 11.0 | 10,900 | 4.1 | 44 | 2,840 | 3,480 | 1,060 | 1,280 | 790  | 1,160 | 1,130 |
| Oak, red (Quercus rubra).                      | Arkansas, Louisiana, Indiana, Tennessee. | 21 | 11 | 62  | 84  | .56 | .65 | 64 | 14.2 | 3.9 | 8.3  | 3,700 | 7,700  | 1,290 | .65  | 11.5 | 10,400 | 3.9 | 41 | 2,330 | 3,200 | 730   | 1,120 | 740  | 1,020 | 950   |
| Oak, Spanish (highland) (Quercus digitata).    | Louisiana.                               | 4  | 20 | 46  | 90  | .52 | .62 | 62 | 16.3 | 4.5 | 8.7  | 4,200 | 6,900  | 1,140 | .93  | 8.0  | 9,100  | 3.1 | 29 | 2,180 | 3,030 | 680   | 930   | 480  | 910   | 860   |
| Oak, Spanish (lowland) (Quercus pagodaefolia). | .....do.                                 | 3  | 7  | 63  | 78  | .61 | .71 | 67 | 16.4 | 5.2 | 10.8 | 6,500 | 10,800 | 1,790 | 1.32 | 14.7 | 12,300 | 3.8 | 54 | 3,760 | 4,620 | 940   | 1,320 | 800  | 1,270 | 1,240 |
| Oak, water (Quercus minor).                    | .....do.                                 | 5  | 10 | 61  | 81  | .56 | .68 | 63 | 16.4 | 4.2 | 9.3  | 5,600 | 8,900  | 1,550 | 1.14 | 11.1 | 11,600 | 3.8 | 39 | 3,200 | 3,740 | 770   | 1,240 | 820  | 1,050 | 1,010 |
| Oak, white (Quercus alba).                     | Arkansas, Louisiana, Indiana.            | 20 | 17 | 60  | 88  | .60 | .71 | 62 | 15.8 | 5.3 | 9.0  | 4,700 | 8,300  | 1,250 | 1.08 | 11.5 | 10,700 | 4.2 | 42 | 2,990 | 3,560 | 830   | 1,250 | 770  | 1,120 | 1,060 |

TABLE 1.—Results of tests on 136 species of wood tested in a green condition in the form of small clear pieces—Continued.

| Common and botanical name.                  | Locality where grown. | Number of trees. | Number of rings per inch. | Summerwood (per cent). | Moisture content (per cent). | Specific gravity   |                       | Shrinkage from green to oven-dry condition.    |                                             |                                                 | Static bending.                                         |                                              |                                                       |                                                | Impact bending.                               |                                                         |                                                                | Compression parallel to grain.                                     |                                                         | Tension perpendicular to grain (pounds per square inch). | Shearing strength parallel to grain (pounds per square inch). | Compression perpendicular to grain—fiber stress at elastic limit (pounds per square inch). | End (pounds). | Side (pounds). | Hardness load required to imbed a 0.444-inch ball to one-half its diameter. |                                                     |
|---------------------------------------------|-----------------------|------------------|---------------------------|------------------------|------------------------------|--------------------|-----------------------|------------------------------------------------|---------------------------------------------|-------------------------------------------------|---------------------------------------------------------|----------------------------------------------|-------------------------------------------------------|------------------------------------------------|-----------------------------------------------|---------------------------------------------------------|----------------------------------------------------------------|--------------------------------------------------------------------|---------------------------------------------------------|----------------------------------------------------------|---------------------------------------------------------------|--------------------------------------------------------------------------------------------|---------------|----------------|-----------------------------------------------------------------------------|-----------------------------------------------------|
|                                             |                       |                  |                           |                        |                              | Volume when green. | Volume when oven-dry. | In volume (per cent of dimensions when green). | Radial (per cent of dimensions when green). | Tangential (per cent of dimensions when green). | Fiber stress at elastic limit (pounds per square inch). | Modulus of rupture (pounds per square inch). | Modulus of elasticity (1,000 pounds per square inch). | To elastic limit (inch-pounds per cubic inch). | To maximum load (inch-pounds per cubic inch). | Fiber stress at elastic limit (pounds per square inch). | Work in bending to elastic limit (inch-pounds per cubic inch). | Height of drop causing complete failure, 50-pound hammer (inches). | Fiber stress at elastic limit (pounds per square inch). |                                                          |                                                               |                                                                                            |               |                |                                                                             | Maximum crushing strength (pounds per square inch). |
| 1                                           | 2                     | 3                | 4                         | 5                      | 6                            | 7                  | 8                     | 9                                              | 10                                          | 11                                              | 12                                                      | 13                                           | 14                                                    | 15                                             | 16                                            | 17                                                      | 18                                                             | 19                                                                 | 20                                                      | 21                                                       | 22                                                            | 23                                                                                         | 24            | 25             | 26                                                                          | 27                                                  |
| HARDWOODS—contd.                            |                       |                  |                           |                        |                              |                    |                       |                                                |                                             |                                                 |                                                         |                                              |                                                       |                                                |                                               |                                                         |                                                                |                                                                    |                                                         |                                                          |                                                               |                                                                                            |               |                |                                                                             |                                                     |
| Oak, willow (Quercus phellos).              | Louisiana.....        | 2                | 14                        | 56                     | 94                           | 0.56               | 0.69                  | 67                                             | 18.9                                        | 5.0                                             | 9.6                                                     | 4,400                                        | 7,400                                                 | 1,290                                          | 0.88                                          | 8.8                                                     | 9,200                                                          | 2.9                                                                | 35                                                      | 2,480                                                    | 3,000                                                         | 750                                                                                        | 1,180         | 760            | 1,020                                                                       | 980                                                 |
| Oak, yellow (Quercus velutina).             | Arkansas, Wisconsin.  | 8                | 15                        | 71                     | 78                           | .56                | .67                   | 63                                             | 14.2                                        | 4.5                                             | 9.7                                                     | 4,600                                        | 8,200                                                 | 1,180                                          | 1.20                                          | 12.3                                                    | 10,800                                                         | 4.4                                                                | 40                                                      | 2,870                                                    | 3,400                                                         | 870                                                                                        | 1,180         | 830            | 1,000                                                                       | 1,060                                               |
| Persimmon (Diospyros virginiana).           | Missouri.....         | 5                | 14                        | .....                  | 58                           | .64                | .78                   | 63                                             | 18.3                                        | 7.5                                             | 10.8                                                    | 5,600                                        | 10,000                                                | 1,370                                          | 1.35                                          | 13.0                                                    | 12,100                                                         | 4.5                                                                | 41                                                      | 3,030                                                    | 4,170                                                         | 1,110                                                                                      | 1,470         | 770            | 1,240                                                                       | 1,280                                               |
| Poplar, yellow (Liriodendron tulipifera).   | Tennessee.....        | 5                | 14                        | .....                  | 61                           | .37                | .42                   | 38                                             | 11.4                                        | 4.1                                             | 6.9                                                     | 3,200                                        | 5,600                                                 | 1,210                                          | .48                                           | 5.6                                                     | 8,000                                                          | 2.6                                                                | 17                                                      | 2,000                                                    | 2,550                                                         | 310                                                                                        | 790           | 460            | 420                                                                         | 340                                                 |
| Rhododendron, great (Rhododendron maximum). | do.....               | 5                | 28                        | .....                  | 99                           | .50                | .60                   | 62                                             | 16.2                                        | 6.3                                             | 8.7                                                     | 4,600                                        | 6,900                                                 | 870                                            | 1.38                                          | 12.1                                                    | .....                                                          | .....                                                              | 26                                                      | .....                                                    | 3,470                                                         | 890                                                                                        | 1,240         | .....          | 1,000                                                                       | 860                                                 |
| Sassafras (Sassafras sassafras).            | do.....               | 5                | 19                        | 48                     | 67                           | .42                | .47                   | 44                                             | 10.3                                        | 4.0                                             | 6.2                                                     | 3,600                                        | 6,000                                                 | 910                                            | .80                                           | 7.1                                                     | 8,500                                                          | 3.5                                                                | 37                                                      | 2,410                                                    | 2,730                                                         | 460                                                                                        | 950           | 520            | 610                                                                         | 520                                                 |
| Servicberry (Amelanchier canadensis).       | do.....               | 5                | 19                        | .....                  | 48                           | .66                | .79                   | 61                                             | 18.7                                        | 6.7                                             | 10.8                                                    | 5,600                                        | 9,600                                                 | 1,640                                          | 1.08                                          | 16.2                                                    | 12,200                                                         | 4.1                                                                | 63                                                      | 3,200                                                    | 4,080                                                         | 780                                                                                        | 1,200         | 730            | 1,250                                                                       | 1,240                                               |
| Silverbell-tree (Mohrrodendrum carolinum).  | do.....               | 5                | 20                        | .....                  | 70                           | .42                | .48                   | 44                                             | 12.6                                        | 3.8                                             | 7.6                                                     | 3,500                                        | 6,500                                                 | 1,160                                          | .62                                           | 8.8                                                     | 9,100                                                          | 3.3                                                                | 27                                                      | 2,110                                                    | 2,830                                                         | 430                                                                                        | 930           | 460            | 550                                                                         | 470                                                 |

|                            |    |    |     |     |    |    |    |    |       |       |       |       |       |       |       |       |       |       |     |    |     |     |     |    |       |       |       |       |     |     |       |       |       |     |     |     |
|----------------------------|----|----|-----|-----|----|----|----|----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-----|----|-----|-----|-----|----|-------|-------|-------|-------|-----|-----|-------|-------|-------|-----|-----|-----|
| .....do.....               | 5  | 24 | 69  | 50  | 59 | 53 | 15 | 2  | 6     | 3     | 8     | 9     | 4     | 400   | 7     | 700   | 1     | 320   | .82 | 9  | 8   | 10  | 800 | 4  | 1     | 38    | 2     | 720   | 3   | 250 | 650   | 1     | 160   | 710 | 860 | 730 |
| Sourwood (Oxyden-          | 5  | 9  | 61  | 45  | 45 | 41 | 15 | 2  | 6     | 3     | 8     | 9     | 4     | 400   | 7     | 700   | 1     | 320   | .82 | 9  | 8   | 10  | 800 | 4  | 1     | 38    | 2     | 720   | 3   | 250 | 650   | 1     | 160   | 710 | 860 | 730 |
| drum arboreum).            | 5  | 9  | 61  | 45  | 45 | 41 | 15 | 2  | 6     | 3     | 8     | 9     | 4     | 400   | 7     | 700   | 1     | 320   | .82 | 9  | 8   | 10  | 800 | 4  | 1     | 38    | 2     | 720   | 3   | 250 | 650   | 1     | 160   | 710 | 860 | 730 |
| Sumac, staghorn (Rhus      | 5  | 17 | 38  | 62  | 47 | 54 | 48 | 12 | 7     | 5     | 0     | 7     | 3     | 200   | 6     | 600   | 810   | .78   | 12  | 0  | 8   | 200 | 3   | 2  | 33    | 1     | 950   | 2     | 800 | 580 | 1     | 050   | 660   | 840 | 740 |     |
| hirta).                    | 5  | 17 | 38  | 62  | 47 | 54 | 48 | 12 | 7     | 5     | 0     | 7     | 3     | 200   | 6     | 600   | 810   | .78   | 12  | 0  | 8   | 200 | 3   | 2  | 33    | 1     | 950   | 2     | 800 | 580 | 1     | 050   | 660   | 840 | 740 |     |
| Sugarberry (Celtis mis-    | 10 | 16 | 77  | 83  | 46 | 54 | 52 | 14 | 2     | 5     | 1     | 7     | 6     | 3     | 300   | 6     | 500   | 1,060 | .60 | 7  | 5   | 8   | 800 | 3  | 3     | 26    | 2     | 390   | 2   | 920 | 450   | 1     | 000   | 630 | 700 | 610 |
| sissipiliensis).           | 5  | 15 | 89  | 40  | 48 | 47 | 13 | 0  | 4     | 4     | 7     | 5     | 3     | 400   | 6     | 100   | 1,190 | .55   | 8   | 3  | 8   | 600 | 2   | 9  | 23    | 2     | 250   | 2     | 610 | 330 | 830   | 450   | 570   | 500 |     |     |
| Sycamore (Platanus oc-     | 5  | 12 | 81  | 51  | 56 | 58 | 11 | 3  | 5     | 2     | 7     | 1     | 5     | 400   | 9     | 500   | 1,420 | 1.16  | 14  | 6  | 11  | 900 | 4   | 5  | 37    | 3     | 600   | 4     | 300 | 600 | 1     | 220   | 570   | 960 | 900 |     |
| cidentalis).               | 10 | 5  | 138 | 34  | 41 | 50 | 13 | 8  | 2     | 6     | 7     | 8     | 1     | 800   | 3     | 800   | 500   | .36   | 10  | 8  | 5   | 100 | 2   | 0  | 36    | 9     | 70    | 1     | 510 | 210 | 620   | 430   | 350   | 360 |     |     |
| Umbrella, Fraser (Mag-     | 5  | 5  | 105 | 39  | 47 | 50 | 13 | 8  | 2     | 9     | 9     | 0     | 3     | 100   | 5     | 600   | 1,020 | .58   | 10  | 8  | 5   | 700 | 2   | 5  | 33    | 1     | 810   | 2     | 340 | 330 | 870   | 360   | 490   | 500 |     |     |
| nolia Fraser).             | 5  | 14 | 70  | 56  | 71 | 59 | 18 | 8  | ..... | ..... | ..... | ..... | ..... | 5,000 | 8,300 | 1,110 | 1.29  | 19    | 5   | 12 | 400 | 6   | 3   | 40 | ..... | 3,400 | ..... | ..... | 620 | 1   | 120   | ..... | 1,010 | 980 |     |     |
| Walnut, black (Juglans     | 10 | 20 | 36  | 35  | 31 | 34 | 27 | 8  | 1     | 2     | 5     | 5     | 1     | 3,300 | 5,200 | 950   | .64   | 5     | 0   | 7  | 100 | 2   | 4   | 17 | 2     | 500   | 2     | 840   | 310 | 720 | 210   | 430   | 270   |     |     |     |
| nigra), black (Salix       | 5  | 23 | 36  | 55  | 23 | 32 | 28 | 7  | 0     | 2     | 1     | 4     | 9     | 2,600 | 4,200 | 640   | .60   | 5     | 7   | 5  | 300 | 2   | 0   | 15 | 1     | 420   | 1     | 990   | 290 | 620 | 240   | 320   | 230   |     |     |     |
| nigra), black (Salix       | 10 | 16 | 31  | 87  | 41 | 47 | 48 | 10 | 7     | 3     | 8     | 0     | 0     | 4,000 | 6,800 | 1,190 | .86   | 6     | 4   | 8  | 000 | 2   | 6   | 24 | 3     | 100   | 3     | 490   | 470 | 820 | 280   | 470   | 380   |     |     |     |
| Willow, western black      | 5  | 31 | 40  | 40  | 44 | 35 | 7  | 9  | 1     | 9     | 5     | 0     | 3     | 600   | 6,200 | 960   | .77   | 9     | 5   | 8  | 600 | 3   | 2   | 27 | 2     | 390   | 2     | 880   | 410 | 820 | 260   | 520   | 410   |     |     |     |
| (Salix lasiandra).         | 18 | 13 | 35  | 36  | 45 | 52 | 38 | 12 | 6     | 5     | 0     | 7     | 9     | 5,000 | 7,800 | 1,580 | .86   | 6     | 7   | 9  | 400 | 2   | 9   | 25 | 3     | 400   | 3     | 940   | 530 | 910 | 200   | 510   | 470   |     |     |     |
| Witch hazel (Hamame-       | 10 | 22 | 27  | 38  | 40 | 44 | 34 | 10 | 6     | 3     | 6     | 2     | 3     | 600   | 6,400 | 1,180 | .65   | 6     | 8   | 9  | 100 | 3   | 0   | 20 | 2     | 520   | 3     | 000   | 450 | 880 | 350   | 450   | 400   |     |     |     |
| lis virginiana).           | 5  | 15 | 14  | 47  | 31 | 32 | 28 | 9  | 0     | 2     | 5     | 7     | 1     | 2,400 | 4,400 | 800   | .39   | 4     | 4   | 5  | 300 | 1   | 6   | 9  | 1     | 660   | 2     | 060   | 310 | 610 | ..... | 280   | 220   |     |     |     |
| CONFERS.                   | 20 | 8  | 26  | 102 | 37 | 42 | 47 | 14 | 1     | 4     | 5     | 10    | 0     | 3,900 | 6,300 | 1,300 | .60   | 6     | 0   | 7  | 800 | 2   | 2   | 21 | 2     | 380   | 2     | 930   | 320 | 670 | 240   | 360   | 310   |     |     |     |
| Cedar, incense (Libocedrus | 5  | 12 | 26  | 117 | 34 | 41 | 45 | 10 | 8     | 2     | 8     | 6     | 6     | 3,000 | 4,900 | 960   | .52   | 4     | 7   | 6  | 900 | 2   | 3   | 16 | 2     | 220   | 2     | 400   | 210 | 610 | 180   | 290   | 290   |     |     |     |
| decurrens).                | 10 | 18 | 30  | 94  | 37 | 42 | 44 | 10 | 6     | 3     | 2     | 7     | 2     | 3,600 | 6,100 | 1,300 | .58   | 5     | 6   | 8  | 100 | 2   | 6   | 22 | 2     | 680   | 3     | 010   | 340 | 760 | 230   | 420   | 360   |     |     |     |
| Cedar, Port O rford        | 5  | 23 | 17  | 41  | 35 | 41 | 31 | 13 | 6     | 4     | 9     | 9     | 1     | 3,400 | 5,700 | 1,280 | .53   | 6     | 2   | 7  | 900 | 2   | 6   | 20 | 2     | 370   | 2     | 700   | 310 | 700 | 180   | 300   | 250   |     |     |     |
| (Chamaecyparis law-        | 5  | 10 | 30  | 156 | 35 | 44 | 56 | 10 | 2     | 3     | 4     | 7     | 0     | 3,900 | 6,000 | 1,130 | .77   | 5     | 2   | 7  | 200 | 2   | 2   | 18 | 2     | 610   | 2     | 800   | 440 | 730 | 260   | 380   | 330   |     |     |     |
| soniana).                  | 5  | 23 | 45  | 70  | 42 | 48 | 45 | 10 | 8     | 4     | 4     | 7     | 1     | 3,500 | 6,000 | 940   | .78   | 9     | 4   | 8  | 800 | 3   | 6   | 36 | 2     | 590   | 2     | 890   | 400 | 880 | 360   | 580   | 460   |     |     |     |
| Cedar, white (Thuja        | 5  | 23 | 45  | 70  | 42 | 48 | 45 | 10 | 8     | 4     | 4     | 7     | 1     | 3,500 | 6,000 | 940   | .78   | 9     | 4   | 8  | 800 | 3   | 6   | 36 | 2     | 590   | 2     | 890   | 400 | 880 | 360   | 580   | 460   |     |     |     |
| occidentalis).             | 5  | 23 | 45  | 70  | 42 | 48 | 45 | 10 | 8     | 4     | 4     | 7     | 1     | 3,500 | 6,000 | 940   | .78   | 9     | 4   | 8  | 800 | 3   | 6   | 36 | 2     | 590   | 2     | 890   | 400 | 880 | 360   | 580   | 460   |     |     |     |
| Cypress, bald (Taxo-       | 5  | 23 | 45  | 70  | 42 | 48 | 45 | 10 | 8     | 4     | 4     | 7     | 1     | 3,500 | 6,000 | 940   | .78   | 9     | 4   | 8  | 800 | 3   | 6   | 36 | 2     | 590   | 2     | 890   | 400 | 880 | 360   | 580   | 460   |     |     |     |
| dium distichum).           | 5  | 23 | 45  | 70  | 42 | 48 | 45 | 10 | 8     | 4     | 4     | 7     | 1     | 3,500 | 6,000 | 940   | .78   | 9     | 4   | 8  | 800 | 3   | 6   | 36 | 2     | 590   | 2     | 890   | 400 | 880 | 360   | 580   | 460   |     |     |     |
| Cypress, yellow (Cha-      | 5  | 23 | 45  | 70  | 42 | 48 | 45 | 10 | 8     | 4     | 4     | 7     | 1     | 3,500 | 6,000 | 940   | .78   | 9     | 4   | 8  | 800 | 3   | 6   | 36 | 2     | 590   | 2     | 890   | 400 | 880 | 360   | 580   | 460   |     |     |     |
| mascypris nootka-          | 18 | 13 | 35  | 36  | 45 | 52 | 38 | 12 | 6     | 5     | 0     | 7     | 9     | 5,000 | 7,800 | 1,580 | .86   | 6     | 7   | 9  | 400 | 2   | 9   | 25 | 3     | 400   | 3     | 940   | 530 | 910 | 200   | 510   | 470   |     |     |     |
| ten is).                   | 10 | 22 | 27  | 38  | 40 | 44 | 34 | 10 | 6     | 3     | 6     | 2     | 3     | 600   | 6,400 | 1,180 | .65   | 6     | 8   | 9  | 100 | 3   | 0   | 20 | 2     | 520   | 3     | 000   | 450 | 880 | 350   | 450   | 400   |     |     |     |
| Douglas fir (Pseudo-       | 5  | 15 | 14  | 47  | 31 | 32 | 28 | 9  | 0     | 2     | 5     | 7     | 1     | 2,400 | 4,400 | 800   | .39   | 4     | 4   | 5  | 300 | 1   | 6   | 9  | 1     | 660   | 2     | 060   | 310 | 610 | ..... | 280   | 220   |     |     |     |
| tsuga taxifolia).          | 20 | 8  | 26  | 102 | 37 | 42 | 47 | 14 | 1     | 4     | 5     | 10    | 0     | 3,900 | 6,300 | 1,300 | .60   | 6     | 0   | 7  | 800 | 2   | 2   | 21 | 2     | 380   | 2     | 930   | 320 | 670 | 240   | 360   | 310   |     |     |     |
| Do.....                    | 5  | 12 | 26  | 117 | 34 | 41 | 45 | 10 | 8     | 2     | 8     | 6     | 6     | 3,000 | 4,900 | 960   | .52   | 4     | 7   | 6  | 900 | 2   | 3   | 16 | 2     | 220   | 2     | 400   | 210 | 610 | 180   | 290   | 290   |     |     |     |
| Fir, Alpine (Abies lasio-  | 10 | 18 | 30  | 94  | 37 | 42 | 44 | 10 | 6     | 3     | 2     | 7     | 2     | 3,600 | 6,100 | 1,300 | .58   | 5     | 6   | 8  | 100 | 2   | 6   | 22 | 2     | 680   | 3     | 010   | 340 | 760 | 230   | 420   | 360   |     |     |     |
| carpa).                    | 5  | 23 | 17  | 41  | 35 | 41 | 31 | 13 | 6     | 4     | 9     | 9     | 1     | 3,400 | 5,700 | 1,280 | .53   | 6     | 2   | 7  | 900 | 2   | 6   | 20 | 2     | 370   | 2     | 700   | 310 | 700 | 180   | 300   | 250   |     |     |     |
| Fir, amabilis (Abies       | 5  | 10 | 30  | 156 | 35 | 44 | 56 | 10 | 2     | 3     | 4     | 7     | 0     | 3,900 | 6,000 | 1,130 | .77   | 5     | 2   | 7  | 200 | 2   | 2   | 18 | 2     | 610   | 2     | 800   | 440 | 730 | 260   | 380   | 330   |     |     |     |
| amabilis).                 | 5  | 23 | 45  | 70  | 42 | 48 | 45 | 10 | 8     | 4     | 4     | 7     | 1     | 3,500 | 6,000 | 940   | .78   | 9     | 4   | 8  | 800 | 3   | 6   | 36 | 2     | 590   | 2     | 890   | 400 | 880 | 360   | 580   | 460   |     |     |     |
| Fir, balsam (Abies bal-    | 5  | 23 | 45  | 70  | 42 | 48 | 45 | 10 | 8     | 4     | 4     | 7     | 1     | 3,500 | 6,000 | 940   | .78   | 9     | 4   | 8  | 800 | 3   | 6   | 36 | 2     | 590   | 2     | 890   | 400 | 880 | 360   | 580   | 460   |     |     |     |
| samea).                    | 5  | 23 | 45  | 70  | 42 | 48 | 45 | 10 | 8     | 4     | 4     | 7     | 1     | 3,500 | 6,000 | 940   | .78   | 9     | 4   | 8  | 800 | 3   | 6   | 36 | 2     | 590   | 2     | 890   | 400 | 880 | 360   | 580   | 460   |     |     |     |
| Fir, grand (Abies          | 5  | 23 | 45  | 70  | 42 | 48 | 45 | 10 | 8     | 4     | 4     | 7     | 1     | 3,500 | 6,000 | 940   | .78   | 9     | 4   | 8  | 800 | 3   | 6   | 36 | 2     | 590   | 2     | 890   | 400 | 880 | 360   | 580   | 460   |     |     |     |
| grands).                   | 5  | 23 | 45  | 70  | 42 | 48 | 45 | 10 | 8     | 4     | 4     | 7     | 1     | 3,500 | 6,000 | 940   | .78   | 9     | 4   | 8  | 800 | 3   | 6   | 36 | 2     | 590   | 2     | 890   | 400 | 880 | 360   | 580   | 460   |     |     |     |
| Fir, noble (Abies nobilis) | 5  | 23 | 45  | 70  | 42 | 48 | 45 | 10 | 8     | 4     | 4     | 7     | 1     | 3,500 | 6,000 | 940   | .78   | 9     | 4   | 8  | 800 | 3   | 6   | 36 | 2     | 590   | 2     | 890   | 400 | 880 | 360   | 580   | 460   |     |     |     |
| Fir, white (Abies con-     | 5  | 23 | 45  | 70  | 42 | 48 | 45 | 10 | 8     | 4     | 4     | 7     | 1     | 3,500 | 6,000 | 940   | .78   | 9     | 4   | 8  | 800 | 3   | 6   | 36 | 2     | 590   | 2     | 890   | 400 | 880 | 360   | 580   |       |     |     |     |



TABLE 1.—Results of tests on 126 species of wood tested in a green condition in the form of small clear pieces—Continued.

| Common and botanical name.                              | Locality where grown.                    | Number of trees. | Number of rings per inch. | Summerwood (per cent). | Moisture content (per cent). | Specific gravity oven-dry, based on— |                       | Weight per cubic foot (green) (pounds). | In volume (per cent of dimensions when green). | Shrinkage from green to oven-dry condition. |                                                 |                                                         | Static bending.                              |                                                       |                                                |                                               |                                                         |                                                                | Impact bending.                                                    |                                                         |                                                     |                                                                                            | Compression parallel to grain. |     | Shearing strength parallel to grain (pounds per square inch). | Tension perpendicular to grain (pounds per square inch). | Side (pounds). | End (pounds). | Hardness, load required to imbed a 0.444-inch ball to one-half its diameter. |
|---------------------------------------------------------|------------------------------------------|------------------|---------------------------|------------------------|------------------------------|--------------------------------------|-----------------------|-----------------------------------------|------------------------------------------------|---------------------------------------------|-------------------------------------------------|---------------------------------------------------------|----------------------------------------------|-------------------------------------------------------|------------------------------------------------|-----------------------------------------------|---------------------------------------------------------|----------------------------------------------------------------|--------------------------------------------------------------------|---------------------------------------------------------|-----------------------------------------------------|--------------------------------------------------------------------------------------------|--------------------------------|-----|---------------------------------------------------------------|----------------------------------------------------------|----------------|---------------|------------------------------------------------------------------------------|
|                                                         |                                          |                  |                           |                        |                              | Volume when green.                   | Volume when oven-dry. |                                         |                                                | Radial (per cent of dimensions when green). | Tangential (per cent of dimensions when green). | Fiber stress at elastic limit (pounds per square inch). | Modulus of rupture (pounds per square inch). | Modulus of elasticity (1,000 pounds per square inch). | To elastic limit (inch-pounds per cubic inch). | To maximum load (inch-pounds per cubic inch). | Fiber stress at elastic limit (pounds per square inch). | Work in bending to elastic limit (inch-pounds per cubic inch). | Height of drop causing complete failure, 50-pound hammer (inches). | Fiber stress at elastic limit (pounds per square inch). | Maximum crushing strength (pounds per square inch). | Compression perpendicular to grain—fiber stress at elastic limit (pounds per square inch). |                                |     |                                                               |                                                          |                |               |                                                                              |
| 1                                                       | 2                                        | 3                | 4                         | 5                      | 6                            | 7                                    | 8                     | 9                                       | 10                                             | 11                                          | 12                                              | 13                                                      | 14                                           | 15                                                    | 16                                             | 17                                            | 18                                                      | 19                                                             | 20                                                                 | 21                                                      | 22                                                  | 23                                                                                         | 24                             | 25  | 26                                                            | 27                                                       |                |               |                                                                              |
| CONIFERS—Continued.                                     |                                          |                  |                           |                        |                              |                                      |                       |                                         |                                                |                                             |                                                 |                                                         |                                              |                                                       |                                                |                                               |                                                         |                                                                |                                                                    |                                                         |                                                     |                                                                                            |                                |     |                                                               |                                                          |                |               |                                                                              |
| Hemlock (eastern) (Tsuga canadensis).                   | Tennessee, Wisconsin.                    | 10               | 20                        | 34                     | 105.0                        | .38                                  | .44                   | 48                                      | 10.4                                           | 3.0                                         | 6.4                                             | 4,200                                                   | 6,700                                        | 1,120                                                 | 0.88                                           | 6.8                                           | 7,900                                                   | 2.8                                                            | 20                                                                 | 2,710                                                   | 3,270                                               | 500                                                                                        | 880                            | 260 | 510                                                           | 410                                                      |                |               |                                                                              |
| Hemlock (western) (Tsuga heterophylla).                 | Washington.....                          | 5                | 10                        | 27                     | 71                           | .38                                  | .43                   | 41                                      | 11.6                                           | 4.5                                         | 7.9                                             | 3,400                                                   | 6,100                                        | 1,190                                                 | .58                                            | 6.0                                           | 7,800                                                   | 2.4                                                            | 20                                                                 | 2,200                                                   | 2,800                                               | 350                                                                                        | 810                            | 260 | 540                                                           | 430                                                      |                |               |                                                                              |
| Larch, western (Larix laricina) (western heterophylla). | Montana, Washington.                     | 13               | 32                        | 37                     | 58                           | .48                                  | .59                   | 48                                      | 13.2                                           | 4.2                                         | 8.1                                             | 4,600                                                   | 7,500                                        | 1,350                                                 | 1.01                                           | 7.1                                           | 9,400                                                   | 3.7                                                            | 24                                                                 | 3,250                                                   | 3,800                                               | 500                                                                                        | 920                            | 230 | 470                                                           | 450                                                      |                |               |                                                                              |
| Pine, Cuban (Pinus heterophylla).                       | Florida.....                             | 5                | 17                        | 44                     | 47                           | .58                                  | .68                   | 53                                      | 12.7                                           | 5.9                                         | 7.5                                             | 5,600                                                   | 8,800                                        | 1,630                                                 | 1.10                                           | 7.9                                           | 11,300                                                  | 3.9                                                            | 37                                                                 | 3,950                                                   | 4,470                                               | 500                                                                                        | 1,030                          | 290 | 570                                                           | 630                                                      |                |               |                                                                              |
| Pine, jack (Pinus divaricata).                          | Wisconsin.....                           | 5                | 7                         | 30                     | 105                          | .39                                  | .46                   | 50                                      | 10.4                                           | 3.4                                         | 6.5                                             | 3,000                                                   | 5,400                                        | 920                                                   | .55                                            | 5.9                                           | 7,800                                                   | 3.3                                                            | 30                                                                 | 2,250                                                   | 2,580                                               | 380                                                                                        | 760                            | 310 | 380                                                           | 370                                                      |                |               |                                                                              |
| Pine, Jeffrey (Pinus jeffreyi).                         | California.....                          | 5                | 18                        | 23                     | 101                          | .37                                  | .42                   | 47                                      | 9.9                                            | 4.4                                         | 6.7                                             | 3,200                                                   | 5,000                                        | 980                                                   | .60                                            | 4.7                                           | 7,200                                                   | 2.6                                                            | 21                                                                 | 2,030                                                   | 2,370                                               | 350                                                                                        | 690                            | 260 | 320                                                           | 340                                                      |                |               |                                                                              |
| Pine, loblolly (Pinus taeda).                           | Florida, North Carolina, South Carolina. | 15               | 8                         | 42                     | 70                           | .50                                  | .59                   | 54                                      | 12.6                                           | 5.5                                         | 7.5                                             | 4,400                                                   | 7,500                                        | 1,380                                                 | .81                                            | 8.0                                           | 9,500                                                   | 3.1                                                            | 32                                                                 | 2,870                                                   | 3,580                                               | 550                                                                                        | 900                            | 280 | 400                                                           | 450                                                      |                |               |                                                                              |
| Pine, lodgepole (Pinus contorta).                       | Colorado, Montana, Wyoming.              | 28               | 24                        | 22                     | 65                           | .38                                  | .44                   | 39                                      | 11.5                                           | 4.5                                         | 6.7                                             | 3,000                                                   | 5,500                                        | 1,080                                                 | .49                                            | 5.6                                           | 7,200                                                   | 2.3                                                            | 20                                                                 | 2,100                                                   | 2,610                                               | 310                                                                                        | 690                            | 220 | 320                                                           | 330                                                      |                |               |                                                                              |

|                                         |    |    |       |     |     |     |    |      |     |     |       |        |       |      |      |        |     |    |       |       |       |       |       |       |       |
|-----------------------------------------|----|----|-------|-----|-----|-----|----|------|-----|-----|-------|--------|-------|------|------|--------|-----|----|-------|-------|-------|-------|-------|-------|-------|
| Pine, longleaf (Pinus palustris).       | 34 | 18 | 39    | 47  | .55 | .64 | 50 | 12.3 | 5.3 | 7.5 | 5,400 | 8,700  | 1,630 | 1.00 | 8.0  | 10,800 | 3.5 | 34 | 3,840 | 4,390 | 600   | 1,070 | 290   | 550   | 590   |
| Pine, Norway (Pinus resinosa).          | 5  | 22 | 41    | 54  | .44 | .51 | 42 | 11.5 | 4.6 | 7.2 | 3,700 | 6,400  | 1,380 | .59  | 5.8  | 7,500  | 2.2 | 28 | 2,470 | 3,080 | 360   | 780   | 190   | 360   | 340   |
| Pine, pitch (Pinus rigida).             | 5  | 12 | 30    | 85  | .47 | .54 | 54 | 11.7 | 4.8 | 7.4 | 3,700 | 6,700  | 1,120 | .75  | 8.5  | 9,100  | 3.4 | 29 | 2,100 | 3,040 | 510   | 950   | 350   | 460   | 480   |
| Pine, pond (Pinus serotina).            | 5  | 13 | 35    | 56  | .50 | .58 | 49 | 11.2 | 5.1 | 7.1 | 4,500 | 7,400  | 1,280 | .93  | 7.5  | 9,400  | 3.2 | 33 | 2,990 | 3,660 | 540   | 940   | 280   | 460   | 510   |
| Pine, shortleaf (Pinus echinata).       | 12 | 12 | 40    | 64  | .50 | .58 | 50 | 12.6 | 5.1 | 8.2 | 4,500 | 8,000  | 1,450 | .79  | 8.7  | 11,200 | 4.0 | 39 | 3,650 | 3,810 | 480   | 890   | 330   | 490   | 560   |
| Pine, sugar (Pinus lambertiana).        | 5  | 12 | 34    | 123 | .36 | .39 | 50 | 8.4  | 2.9 | 5.6 | 3,300 | 5,300  | 970   | .66  | 5.0  | 6,700  | 2.3 | 17 | 2,340 | 2,600 | 350   | 710   | 270   | 330   | 320   |
| Pine, table - mountain (Pinus pungens). | 5  | 15 | 29    | 75  | .49 | .55 | 54 | 10.9 | 3.4 | 6.8 | 4,500 | 7,500  | 1,270 | .94  | 8.1  | 10,200 | 3.8 | 29 | 2,980 | 3,540 | 500   | 960   | 320   | 480   | 490   |
| Pine, western white (Pinus monticola).  | 5  | 28 | 33    | 58  | .39 | .45 | 39 | 11.5 | 4.1 | 7.4 | 3,500 | 5,700  | 1,330 | .54  | 5.1  | 7,600  | 2.3 | 23 | 2,770 | 3,070 | 300   | 710   | 250   | 330   | 330   |
| Pine, western yellow (Pinus ponderosa). | 25 | 20 | 22    | 95  | .38 | .42 | 46 | 10.0 | 3.9 | 6.4 | 3,100 | 5,200  | 1,010 | .54  | 5.1  | 6,700  | 2.3 | 19 | 2,080 | 2,460 | 340   | 680   | 280   | 310   | 320   |
| Pine, white (Pinus strobus).            | 5  | 16 | 31    | 74  | .36 | .39 | 39 | 7.8  | 2.2 | 5.9 | 3,400 | 5,300  | 1,070 | .62  | 5.9  | 6,500  | 2.1 | 18 | 2,370 | 2,720 | 310   | 640   | 260   | 300   | 300   |
| Spruce, Engelmann (Picea engelmanni).   | 10 | 14 | 14    | 100 | .31 | .35 | 38 | 10.4 | 3.4 | 6.6 | 2,500 | 4,200  | 830   | .43  | 4.9  | 5,800  | 1.9 | 14 | 1,740 | 1,980 | 290   | 590   | ..... | 250   | 240   |
| Spruce, red (Picea rubens).             | 9  | 17 | 27    | 43  | .38 | .41 | 34 | 11.8 | 3.8 | 7.8 | 3,400 | 5,700  | 1,180 | .56  | 6.1  | 7,200  | 2.3 | 18 | 2,300 | 2,740 | 350   | 770   | 220   | 420   | 350   |
| Spruce, Sitka (Picea sitchensis).       | 5  | 9  | 24    | 53  | .34 | .37 | 33 | 11.2 | 4.5 | 7.4 | 3,000 | 5,500  | 1,180 | .44  | 6.4  | 7,900  | 2.5 | 29 | 2,280 | 2,600 | 330   | 780   | 230   | 430   | 370   |
| Spruce, white (Picea canadensis).       | 7  | 14 | 27    | 46  | .30 | .43 | 33 | 14.8 | 3.7 | 7.3 | 3,300 | 5,400  | 980   | .66  | 5.7  | 6,800  | 2.0 | 20 | 2,280 | 2,380 | 270   | 670   | 200   | 300   | 280   |
| Tamarack (Larix laricina).              | 5  | 20 | 38    | 52  | .49 | .56 | 47 | 13.6 | 3.7 | 7.4 | 4,200 | 7,200  | 1,240 | .84  | 7.2  | 7,800  | 2.7 | 28 | 3,010 | 3,480 | 480   | 860   | 260   | 400   | 380   |
| Yew, western (Taxus brevifolia).        | 5  | 27 | ..... | 44  | .60 | .67 | 54 | 9.7  | 4.0 | 5.4 | 6,500 | 10,100 | 990   | 2.46 | 20.2 | 13,100 | 6.2 | 38 | 3,400 | 4,000 | 1,040 | 1,620 | 450   | 1,340 | 1,150 |

**TABLE 2.**

Table 2 is to be considered supplementary to Table 1. In using this table attention should be given to the comments on "Data on air-dry timber," page 7, to the explanation of column heads, pages 7 to 18, to the figures on change of properties with changes of moisture as given under "Shrinkage from green to oven dry," page 12, and in column 2 of Table 3; also to the explanation of column 2 of Table 3. (See p. 18.)



TABLE 2.—*Results of tests on 126 species of wood tested in an air-dry condition in the form of small clear pieces.*

[Test specimens are 2 by 2 inches in section. Bending specimens are cut 30 inches long; others are shorter, depending on kind of test.]

| Common and botanical name.                       | Locality where grown.    | Number of rings per inch. | Summerwood (per cent.) | Moisture content (per cent.) | Specific gravity, oven dry, based on weight per cubic foot (air dry). | Weight per cubic foot (pounds). | Static bending.                                         |                                              |                                                       |                                                |                                               |                                                | Impact bending.                                         |                                                     |                                                                    |                                                         | Compression parallel to grain.                      |       | Tension perpendicular to grain (pounds per square inch). | Hardness, load required to imbed a 0.444-inch ball to one-half its diameter. |       |
|--------------------------------------------------|--------------------------|---------------------------|------------------------|------------------------------|-----------------------------------------------------------------------|---------------------------------|---------------------------------------------------------|----------------------------------------------|-------------------------------------------------------|------------------------------------------------|-----------------------------------------------|------------------------------------------------|---------------------------------------------------------|-----------------------------------------------------|--------------------------------------------------------------------|---------------------------------------------------------|-----------------------------------------------------|-------|----------------------------------------------------------|------------------------------------------------------------------------------|-------|
|                                                  |                          |                           |                        |                              |                                                                       |                                 | Fiber stress at elastic limit (pounds per square inch). | Modulus of rupture (pounds per square inch). | Modulus of elasticity (1,000 pounds per square inch). | To elastic limit (inch-pounds per cubic inch). | To maximum load (inch-pounds per cubic inch). | Work in bending— (inch-pounds per cubic inch). | Fiber stress at elastic limit (pounds per square inch). | Work to elastic limit (inch-pounds per cubic inch). | Height of drop causing complete failure, 50-pound hammer (inches). | Fiber stress at elastic limit (pounds per square inch). | Maximum crushing strength (pounds per square inch). |       |                                                          |                                                                              |       |
| 1                                                | 2                        | 3                         | 4                      | 5                            | 6                                                                     | 7                               | 8                                                       | 9                                            | 10                                                    | 11                                             | 12                                            | 13                                             | 14                                                      | 15                                                  | 16                                                                 | 17                                                      | 18                                                  | 19    | 20                                                       | 21                                                                           | 22    |
| HARDWOODS.                                       |                          |                           |                        |                              |                                                                       |                                 |                                                         |                                              |                                                       |                                                |                                               |                                                |                                                         |                                                     |                                                                    |                                                         |                                                     |       |                                                          |                                                                              |       |
| Alder, red (Alnus incana)                        | Washington.....          | 11                        | .....                  | 8.6                          | 0.42                                                                  | 29                              | 8,100                                                   | 10,800                                       | 1,440                                                 | 2.37                                           | 8.5                                           | 13,000                                         | 5.9                                                     | 20                                                  | 5,350                                                              | 7,050                                                   | 650                                                 | 1,210 | 430                                                      | 1,170                                                                        | 650   |
| Ash, bitmore (Fraxinus bitmoreana).              | Tennessee.....           | 17                        | 49                     | 5.3                          | .57                                                                   | 38                              | 12,100                                                  | 15,600                                       | 1,760                                                 | 4.60                                           | 11.7                                          | 19,800                                         | 10.4                                                    | 46                                                  | 7,140                                                              | 10,370                                                  | 2,020                                               | 1,970 | 810                                                      | 2,060                                                                        | 1,330 |
| Ash, black (Fraxinus nigra).                     | Michigan, Wisconsin      | 24                        | 52                     | 10.4                         | .50                                                                   | 34                              | 8,300                                                   | 13,900                                       | 1,680                                                 | 1.81                                           | 15.5                                          | 12,200                                         | 5.3                                                     | 36                                                  | 5,070                                                              | 6,890                                                   | 1,080                                               | 1,730 | 730                                                      | 1,250                                                                        | 890   |
| Ash, blue (Fraxinus quadrangulata).              | Kentucky.....            | 12                        | 49                     | 9.6                          | .58                                                                   | 40                              | 8,700                                                   | 14,800                                       | 1,430                                                 | 3.00                                           | 14.3                                          | 20,600                                         | 10.5                                                    | 42                                                  | 6,120                                                              | 7,740                                                   | 1,910                                               | 2,150 | 440                                                      | 1,890                                                                        | 1,360 |
| Ash, green (Fraxinus lanceolata).                | Missouri, Louisiana...   | 18                        | 58                     | 10.4                         | .57                                                                   | 39                              | 9,460                                                   | 14,900                                       | 1,690                                                 | 3.00                                           | 13.6                                          | 17,400                                         | 8.2                                                     | 31                                                  | 5,330                                                              | 7,580                                                   | 1,760                                               | 2,080 | 710                                                      | 1,770                                                                        | 1,260 |
| Ash, Oregon (Fraxinus oregona).                  | Oregon.....              | 12                        | 63                     | 8.4                          | .57                                                                   | 39                              | 8,000                                                   | 14,500                                       | 1,430                                                 | 2.58                                           | 15.1                                          | 15,000                                         | 6.2                                                     | 31                                                  | 4,710                                                              | 7,100                                                   | 2,000                                               | 2,090 | 780                                                      | 1,670                                                                        | 1,300 |
| Ash, pumpkin (Fraxinus profunda).                | Missouri.....            | 21                        | 46                     | 9.6                          | .53                                                                   | 36                              | 7,000                                                   | 11,800                                       | 1,310                                                 | 2.11                                           | 7.8                                           | 15,200                                         | 7.9                                                     | 22                                                  | 4,040                                                              | 6,300                                                   | 2,000                                               | 1,890 | 830                                                      | 1,540                                                                        | 1,030 |
| Ash, white (forest grown) (Fraxinus americana).  | Arkansas, West Virginia. | 16                        | 50                     | 8.7                          | .58                                                                   | 40                              | 10,200                                                  | 16,800                                       | 1,810                                                 | 3.29                                           | 15.1                                          | 17,000                                         | 8.8                                                     | 36                                                  | 5,600                                                              | 8,190                                                   | 1,540                                               | 2,110 | 880                                                      | 1,950                                                                        | 1,320 |
| Ash, white (second growth) (Fraxinus americana). | New York.....            | 9                         | 63                     | 9.5                          | .64                                                                   | 44                              | 13,000                                                  | 18,600                                       | 1,980                                                 | 4.80                                           | 17.0                                          | 23,800                                         | 12.8                                                    | 46                                                  | 8,500                                                              | 9,420                                                   | 2,090                                               | 2,520 | 1,130                                                    | 2,240                                                                        | 1,680 |

TABLE 2.—Results of tests on 126 species of wood tested in an air-dry condition in the form of small clear pieces—Continued.

| Common and botanical name.                           | Locality where grown.    | 3  | 4     | 5    | 6     | 7  | Static bending.                 |        |                                                         |      |                                              |        | Impact bending.                                       |    |                                               |        | Compression parallel to grain.                          |       | Tension perpendicular to grain (pounds per square inch). | Hardness, load required to imbed a 0.444-inch ball to one-half its diameter. |                                                |  |                                                                    |  |                                                         |  |                                                     |  |                                                              |  |                                                                   |  |  |  |  |  |  |  |  |  |
|------------------------------------------------------|--------------------------|----|-------|------|-------|----|---------------------------------|--------|---------------------------------------------------------|------|----------------------------------------------|--------|-------------------------------------------------------|----|-----------------------------------------------|--------|---------------------------------------------------------|-------|----------------------------------------------------------|------------------------------------------------------------------------------|------------------------------------------------|--|--------------------------------------------------------------------|--|---------------------------------------------------------|--|-----------------------------------------------------|--|--------------------------------------------------------------|--|-------------------------------------------------------------------|--|--|--|--|--|--|--|--|--|
|                                                      |                          |    |       |      |       |    | Weight per cubic foot (air dry) |        | Fiber stress at elastic limit (pounds per square inch). |      | Modulus of rupture (pounds per square inch). |        | Modulus of elasticity (1,000 pounds per square inch). |    | Work in bending—(inch-pounds per cubic inch). |        | Fiber stress at elastic limit (pounds per square inch). |       |                                                          |                                                                              | Work to elastic limit (pounds per cubic inch). |  | Height of drop causing complete failure, 50-pound hammer (inches). |  | Fiber stress at elastic limit (pounds per square inch). |  | Maximum crushing strength (pounds per square inch). |  | Compression perpendicular to grain—(pounds per square inch). |  | Shearing strength parallel to the grain (pounds per square inch). |  |  |  |  |  |  |  |  |  |
| 1                                                    | 2                        |    |       |      |       |    | 8                               | 9      | 10                                                      | 11   | 12                                           | 13     | 14                                                    | 15 | 16                                            | 17     | 18                                                      | 19    | 20                                                       | 21                                                                           | 22                                             |  |                                                                    |  |                                                         |  |                                                     |  |                                                              |  |                                                                   |  |  |  |  |  |  |  |  |  |
| HARDWOODS—contd.                                     |                          |    |       |      |       |    |                                 |        |                                                         |      |                                              |        |                                                       |    |                                               |        |                                                         |       |                                                          |                                                                              |                                                |  |                                                                    |  |                                                         |  |                                                     |  |                                                              |  |                                                                   |  |  |  |  |  |  |  |  |  |
| Aspen ( <i>Populus tremuloides</i> ).                | Wisconsin.....           | 8  | ..... | 5.2  | 0.42  | 28 | 7,600                           | 10,800 | 1,290                                                   | 2.43 | 7.3                                          | 10,500 | 4.0                                                   | 24 | 4,490                                         | 6,400  | 550                                                     | 890   | 380                                                      | 850                                                                          | 420                                            |  |                                                                    |  |                                                         |  |                                                     |  |                                                              |  |                                                                   |  |  |  |  |  |  |  |  |  |
| Aspen, large-tooth ( <i>Populus grandidentata</i> ). | .....do                  | 8  | ..... | 8.0  | ..... | 27 | 7,100                           | 10,900 | 1,640                                                   | 1.83 | 6.7                                          | 15,100 | 7.0                                                   | 27 | 5,060                                         | 7,080  | 650                                                     | 1,300 | 380                                                      | 710                                                                          | 460                                            |  |                                                                    |  |                                                         |  |                                                     |  |                                                              |  |                                                                   |  |  |  |  |  |  |  |  |  |
| Basswood ( <i>Tilia americana</i> ).                 | Pennsylvania, Wisconsin. | 19 | 29    | 8.4  | .38   | 26 | 7,300                           | 10,200 | 1,580                                                   | 1.99 | 8.1                                          | 11,200 | 4.6                                                   | 16 | 4,430                                         | 5,980  | 580                                                     | 1,240 | 370                                                      | 590                                                                          | 450                                            |  |                                                                    |  |                                                         |  |                                                     |  |                                                              |  |                                                                   |  |  |  |  |  |  |  |  |  |
| Beech ( <i>Fagus atropur-nicea</i> ).                | Indiana, Pennsylvania.   | 19 | 30    | 11.2 | .63   | 44 | 9,000                           | 15,000 | 1,680                                                   | 2.91 | 13.7                                         | 19,700 | 9.2                                                   | 35 | 4,870                                         | 7,400  | 1,340                                                   | 1,970 | 890                                                      | 1,400                                                                        | 1,190                                          |  |                                                                    |  |                                                         |  |                                                     |  |                                                              |  |                                                                   |  |  |  |  |  |  |  |  |  |
| Birch, paper ( <i>Betula papyrifera</i> ).           | Wisconsin.....           | 6  | 36    | 4.2  | .58   | 38 | 11,400                          | 16,000 | 1,810                                                   | 4.32 | 13.2                                         | 13,800 | 6.6                                                   | 21 | 6,780                                         | 9,470  | 910                                                     | 1,630 | .....                                                    | 1,490                                                                        | 1,280                                          |  |                                                                    |  |                                                         |  |                                                     |  |                                                              |  |                                                                   |  |  |  |  |  |  |  |  |  |
| Birch, sweet ( <i>Betula lenta</i> ).                | Pennsylvania.....        | 27 | ..... | 9.0  | .66   | 45 | 13,300                          | 19,600 | 2,140                                                   | 4.56 | 17.0                                         | 26,700 | 13.2                                                  | 48 | 7,220                                         | 10,680 | 1,750                                                   | 2,680 | 610                                                      | 2,090                                                                        | 1,490                                          |  |                                                                    |  |                                                         |  |                                                     |  |                                                              |  |                                                                   |  |  |  |  |  |  |  |  |  |
| Birch, yellow ( <i>Betula lucida</i> ).              | Pennsylvania, Wisconsin. | 19 | 26    | 9.6  | .63   | 44 | 12,300                          | 18,900 | 2,200                                                   | 3.93 | 20.2                                         | 21,200 | 9.9                                                   | 58 | 7,720                                         | 9,760  | 1,410                                                   | 1,880 | 890                                                      | 1,590                                                                        | 1,320                                          |  |                                                                    |  |                                                         |  |                                                     |  |                                                              |  |                                                                   |  |  |  |  |  |  |  |  |  |
| Buckeye, yellow ( <i>Aesculus octandra</i> ).        | Tennessee.....           | 15 | ..... | 6.2  | .38   | 25 | 7,000                           | 9,300  | 1,280                                                   | 2.20 | 6.2                                          | 12,700 | 6.4                                                   | 14 | 4,220                                         | 5,870  | 640                                                     | 1,140 | 660                                                      | 550                                                                          | 400                                            |  |                                                                    |  |                                                         |  |                                                     |  |                                                              |  |                                                                   |  |  |  |  |  |  |  |  |  |
| Buckthorn, eastern ( <i>Rhamnus purshiana</i> ).     | Oregon.....              | 17 | ..... | 4.0  | .53   | 34 | 8,500                           | 10,500 | 1,240                                                   | 3.28 | 5.7                                          | 11,200 | 5.4                                                   | 16 | 5,510                                         | 9,190  | 2,000                                                   | 1,990 | .....                                                    | 1,790                                                                        | 1,280                                          |  |                                                                    |  |                                                         |  |                                                     |  |                                                              |  |                                                                   |  |  |  |  |  |  |  |  |  |
| Butternut ( <i>Juglans cinerea</i> ).                | Tennessee, Wisconsin.    | 9  | ..... | 7.6  | .39   | 26 | 7,300                           | 9,300  | 1,260                                                   | 2.32 | 8.2                                          | 12,900 | 5.7                                                   | 24 | 4,490                                         | 6,680  | 760                                                     | 1,300 | 440                                                      | 650                                                                          | 530                                            |  |                                                                    |  |                                                         |  |                                                     |  |                                                              |  |                                                                   |  |  |  |  |  |  |  |  |  |
| Cherry, black ( <i>Prunus serotina</i> ).            | Pennsylvania.....        | 11 | ..... | 9.2  | .51   | 35 | 11,000                          | 13,800 | 1,540                                                   | 4.48 | 11.0                                         | 14,800 | 5.9                                                   | 28 | 7,330                                         | 8,370  | 1,020                                                   | 1,930 | 560                                                      | 1,090                                                                        | 1,030                                          |  |                                                                    |  |                                                         |  |                                                     |  |                                                              |  |                                                                   |  |  |  |  |  |  |  |  |  |

|                                                          |       |      |      |    |        |        |       |      |      |        |       |       |        |        |       |       |       |       |       |
|----------------------------------------------------------|-------|------|------|----|--------|--------|-------|------|------|--------|-------|-------|--------|--------|-------|-------|-------|-------|-------|
| Cherry, wild red ( <i>Prunus pennsylvanica</i> ).        | 6     | 6.6  | .41  | 27 | 7,800  | 10,700 | 1,400 | 2.54 | 9.3  | 12,100 | 5.2   | 36    | 5,460  | 6,490  | 700   | 1,240 | 340   | 930   | 580   |
| Chestnut ( <i>Castanea dentata</i> ).                    | 10    | 8.6  | .44  | 30 | 7,400  | 9,700  | 1,330 | 2.41 | 6.4  | 11,500 | 5.4   | 18    | 4,420  | 6,620  | 930   | 1,160 | 470   | 780   | 580   |
| Chinquapin, western ( <i>Castanopsis chrysophylla</i> ). | 15    | 4.8  | .48  | 31 | 11,900 | 14,100 | 1,410 | 6.14 | 9.5  | 12,500 | 6.0   | 29    | 5,780  | 7,970  | 860   | 1,450 | ..... | 920   | 830   |
| Cottonwood ( <i>Populus deltoides</i> ).                 | 6     | 4.7  | .43  | 28 | 8,600  | 11,400 | 1,640 | 2.61 | 7.4  | 7,500  | 2.4   | 19    | 5,060  | 7,830  | 730   | 1,120 | 700   | 740   | 480   |
| Cottonwood, black ( <i>Populus trichocarpa</i> ).        | 6     | 8.5  | .36  | 24 | 6,200  | 9,600  | 1,310 | 1.62 | 7.2  | 10,900 | 4.4   | 22    | 4,410  | 5,440  | 460   | 1,160 | 340   | 670   | 390   |
| Cucumber tree ( <i>Magnolia acuminata</i> ).             | 14    | 6.8  | .50  | 33 | 10,700 | 15,400 | 1,940 | 3.22 | 13.4 | 17,800 | 7.6   | 37    | 6,020  | 8,540  | 860   | 1,530 | 815   | 1,160 | 790   |
| Dogwood (flowering) ( <i>Cornus florida</i> ).           | 24    | 7.5  | .77  | 52 | 11,800 | 18,300 | 1,700 | 4.63 | 18.9 | 19,300 | 10.1  | 40    | 6,030  | 7,090  | 2,470 | 2,740 | 1,730 | 2,980 | 2,530 |
| Dogwood, western ( <i>Cornus nuttallii</i> ).            | 21    | 5.3  | .68  | 45 | 10,100 | 12,200 | 1,760 | 3.26 | 8.5  | 10,900 | 3.8   | 26    | 5,950  | 11,310 | 2,470 | 2,060 | 1,400 | 2,510 | 1,640 |
| Elder, pale ( <i>Sambucus glauca</i> ).                  | 6     | 4.6  | .55  | 36 | 7,600  | 11,300 | 1,120 | 2.51 | 10.7 | 12,100 | 6.9   | 30    | 4,140  | 6,990  | 980   | ..... | ..... | 920   | 900   |
| Elm, cork ( <i>Ulmus racemosa</i> ).                     | 28    | 8.5  | .66  | 44 | 9,400  | 16,500 | 1,610 | 3.32 | 18.7 | 18,500 | 9.4   | 53    | 5,510  | 8,420  | 1,860 | 2,140 | 740   | 1,730 | 1,470 |
| Elm, slippery ( <i>Ulmus pubescens</i> ).                | 16    | 8.3  | .54  | 37 | 9,400  | 14,900 | 1,570 | 3.28 | 17.3 | 17,800 | 9.4   | 45    | 5,370  | 7,800  | 1,240 | 1,810 | 490   | 1,220 | 900   |
| Elm, white ( <i>Ulmus americana</i> ).                   | 18    | 8.8  | .51  | 35 | 9,200  | 14,600 | 1,490 | 3.46 | 13.7 | 16,600 | 9.9   | 44    | 5,270  | 6,850  | 850   | 1,740 | 610   | 1,240 | 870   |
| Gum, black ( <i>Nyssa sylvatica</i> ).                   | 27    | 7.2  | .52  | 35 | 9,200  | 10,900 | 1,270 | 3.54 | 5.6  | 17,200 | 9.1   | 19    | 4,090  | 7,000  | 1,500 | 1,460 | 470   | 1,380 | 850   |
| Gum, blue ( <i>Eucalyptus globulus</i> ).                | ..... | 5.7  | .82  | 54 | 14,400 | 20,600 | 2,600 | 4.82 | 11.6 | 25,200 | 12.6  | 42    | 11,400 | 13,900 | 2,250 | 2,050 | ..... | 1,840 | 1,650 |
| Gum, cotton ( <i>Nyssa aquatica</i> ).                   | 10    | 6.1  | 0.52 | 34 | 9,800  | 11,300 | 1,370 | 4.19 | 6.4  | 14,700 | 7.8   | 20    | 5,450  | 7,910  | 1,530 | 1,840 | 940   | 1,470 | 990   |
| Gum, red ( <i>Liquidambar styraciflua</i> ).             | 16    | 11.3 | .49  | 34 | 8,400  | 12,300 | 1,500 | 3.39 | 11.8 | 19,300 | 10.4  | 32    | 4,960  | 6,020  | 790   | 1,750 | 870   | 1,010 | 720   |
| Hackberry ( <i>Celtis occidentalis</i> ).                | 12    | 9.2  | .54  | 37 | 6,900  | 12,300 | 1,250 | 2.18 | 12.4 | 15,800 | 8.7   | 42    | 4,200  | 6,450  | 1,330 | 1,790 | 570   | 1,210 | 930   |
| Haw, pear ( <i>Crataegus tomentosa</i> ).                | 11    | 8.6  | .70  | 48 | 9,000  | 17,200 | 1,370 | 3.30 | 23.8 | 13,500 | 5.5   | 20    | 4,750  | 8,420  | 1,880 | 1,920 | ..... | 2,270 | 1,680 |
| Hickory, big shellbark ( <i>Hicoria laevis</i> ).        | 18    | 8.7  | .71  | 48 | 9,800  | 20,500 | 2,040 | 2.59 | 22.4 | 25,100 | 14.5  | 84    | .....  | 9,710  | 2,660 | 2,430 | ..... | ..... | ..... |
| Hickory, bitternut ( <i>Hicoria nimbina</i> ).           | 13    | 9.2  | .68  | 46 | 10,300 | 18,800 | 1,880 | 3.19 | 17.9 | 26,500 | 14.0  | 66    | .....  | 10,600 | 2,390 | 2,050 | ..... | ..... | ..... |
| Hickory, mockernut ( <i>Hicoria alba</i> ).              | 18    | 8.9  | .75  | 50 | 13,500 | 21,600 | 2,380 | 4.19 | 22.0 | 21,900 | 10.6  | 74    | .....  | 10,610 | 2,540 | 1,900 | ..... | ..... | ..... |
| Hickory, nutmeg ( <i>Hicoria myristiciformis</i> ).      | ..... | 8.9  | .62  | 42 | 9,200  | 19,300 | 1,820 | 2.40 | 25.7 | .....  | ..... | ..... | .....  | 7,960  | 2,320 | 2,100 | ..... | ..... | ..... |
| Hickory, pecan ( <i>Hicoria pecan</i> ).                 | 12    | 6.2  | .70  | 46 | 12,000 | 16,200 | 1,940 | 4.33 | 13.4 | 20,400 | 10.4  | 41    | 6,170  | 10,890 | 3,350 | 2,540 | 1,310 | 2,370 | 2,140 |
| Hickory, pignut ( <i>Hicoria glabra</i> ).               | 16    | 9.6  | .78  | 53 | 12,700 | 22,500 | 2,410 | 3.87 | 30.2 | 26,200 | 13.4  | 70    | .....  | 10,640 | 2,860 | 2,450 | ..... | ..... | ..... |
| Hickory, shagbark ( <i>Hicoria ovata</i> ).              | 22    | 9.4  | .74  | 50 | 11,900 | 22,600 | 2,290 | 3.55 | 20.3 | 22,500 | 10.7  | 65    | .....  | 10,700 | 2,470 | 2,340 | ..... | ..... | ..... |



TABLE 2.—Results of tests on 126 species of wood tested in an air-dry condition in the form of small clear pieces—Continued.

| Common and botanical name.                     | Locality where grown.        | Number of rings per inch. | Summerwood (per cent). | Moisture content (per cent). | Specific gravity, oven dry, based on volume when air dry. | Weight per cubic foot (air dry). | Static bending.                                         |                                              |                                                       |                                                |                                               |                                                | Impact bending.                                         |                                                     |                                                                    | Compression parallel to grain.                          |                                                     | Tension perpendicular to grain (pounds per square inch). | Hardness, load required to imbed a 0.444-inch ball to one-half its diameter. |                                                                                             |       |
|------------------------------------------------|------------------------------|---------------------------|------------------------|------------------------------|-----------------------------------------------------------|----------------------------------|---------------------------------------------------------|----------------------------------------------|-------------------------------------------------------|------------------------------------------------|-----------------------------------------------|------------------------------------------------|---------------------------------------------------------|-----------------------------------------------------|--------------------------------------------------------------------|---------------------------------------------------------|-----------------------------------------------------|----------------------------------------------------------|------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|-------|
|                                                |                              |                           |                        |                              |                                                           |                                  | Fiber stress at elastic limit (pounds per square inch). | Modulus of rupture (pounds per square inch). | Modulus of elasticity (1,000 pounds per square inch). | To elastic limit (inch-pounds per cubic inch). | To maximum load (inch-pounds per cubic inch). | Work in bending— (inch-pounds per cubic inch). | Fiber stress at elastic limit (pounds per square inch). | Work to elastic limit (inch-pounds per cubic inch). | Height of drop causing complete failure, 50-pound hammer (inches). | Fiber stress at elastic limit (pounds per square inch). | Maximum crushing strength (pounds per square inch). |                                                          |                                                                              | Compression perpendicular to grain— fiber stress at elastic limit (pounds per square inch). |       |
| 1                                              | 2                            | 3                         | 4                      | 5                            | 6                                                         | 7                                | 8                                                       | 9                                            | 10                                                    | 11                                             | 12                                            | 13                                             | 14                                                      | 15                                                  | 16                                                                 | 17                                                      | 18                                                  | 19                                                       | 20                                                                           | 21                                                                                          | 22    |
| HARDWOODS—contd.                               |                              |                           |                        |                              |                                                           |                                  |                                                         |                                              |                                                       |                                                |                                               |                                                |                                                         |                                                     |                                                                    |                                                         |                                                     |                                                          |                                                                              |                                                                                             |       |
| Hickory, water (Hicoria aquatica).             | Mississippi.....             | 15                        | 70                     | 8.8                          | 0.62                                                      | 42 11,800                        | 20,200                                                  | 2,160                                        |                                                       | 3.55                                           | 19.4                                          |                                                |                                                         |                                                     | 52                                                                 | 6,190                                                   | 10,140                                              | 2,210                                                    | 1,860                                                                        |                                                                                             |       |
| Holly, American (Ilex opaca).                  | Tennessee.....               | 27                        |                        | 6.4                          | .60                                                       | 40 8,000                         | 12,700                                                  | 1,230                                        |                                                       | 2.95                                           | 10.6                                          | 14,800                                         | 8.5                                                     | 27                                                  | 4,450                                                              | 7,820                                                   | 1,520                                               | 2,060                                                    | 740                                                                          | 1,770                                                                                       | 1,150 |
| Hornbeam (Ostrya virginiana).                  | Wisconsin.....               | 29                        |                        | 5.6                          | .75                                                       | 49 13,900                        | 18,600                                                  | 2,110                                        |                                                       | 5.34                                           | 14.4                                          | 16,600                                         | 7.6                                                     | 40                                                  | 8,310                                                              | 11,750                                                  | 2,300                                               | 2,110                                                    |                                                                              | 3,150                                                                                       | 2,390 |
| Laurel, California (Umbellularia californica). | Oregon.....                  | 6                         |                        | 4.9                          | .58                                                       | 38 6,700                         | 9,000                                                   | 1,110                                        |                                                       | 2.40                                           | 5.2                                           | 12,500                                         | 6.2                                                     | 22                                                  | 5,220                                                              | 8,140                                                   | 1,930                                               | 2,340                                                    | 950                                                                          | 1,980                                                                                       | 1,460 |
| Laurel, mountain (Kalmia latifolia).           | Tennessee.....               | 24                        |                        | 5.0                          | .72                                                       | 47 10,900                        | 13,200                                                  | 1,410                                        |                                                       | 4.77                                           | 9.1                                           | 17,400                                         | 9.3                                                     | 46                                                  | 5,270                                                              | 7,120                                                   | 2,420                                               |                                                          |                                                                              | 2,670                                                                                       | 2,180 |
| Locust, black (Robinia pseudacacia).           | .....do.....                 | 11                        | 51                     | 10.0                         | .70                                                       | 48 13,800                        | 20,700                                                  | 2,090                                        |                                                       | 5.29                                           | 19.1                                          | 21,600                                         | 10.1                                                    | 59                                                  | 7,790                                                              | 10,880                                                  | 2,520                                               | 2,710                                                    | 620                                                                          | 1,570                                                                                       | 1,730 |
| Locust, honey (Gleditsia triacanthos).         | Missouri.....                | 10                        | 37                     | 6.0                          | .63                                                       | 42 10,700                        | 16,700                                                  | 1,690                                        |                                                       | 3.76                                           | 12.6                                          | 17,000                                         | 9.3                                                     | 45                                                  | 6,520                                                              | 9,520                                                   | 2,800                                               | 2,580                                                    | 820                                                                          | 2,030                                                                                       | 1,600 |
| Madrona (Arbutus menziesii).                   | California, Oregon.....      | 10                        |                        | 4.5                          | .70                                                       | 45 9,500                         | 12,700                                                  | 1,500                                        |                                                       | 3.45                                           | 7.0                                           | 10,700                                         | 4.4                                                     | 16                                                  | 5,790                                                              | 10,800                                                  | 2,640                                               | 2,190                                                    |                                                                              | 2,620                                                                                       | 1,930 |
| Magnolia (evergreen) (Magnolia foetida).       | Louisiana.....               | 15                        |                        | 8.8                          | .51                                                       | 35 7,800                         | 12,500                                                  | 1,480                                        |                                                       | 2.39                                           | 12.3                                          | 15,000                                         | 7.5                                                     | 25                                                  | 3,940                                                              | 6,600                                                   | 1,250                                               | 1,700                                                    | 780                                                                          | 1,480                                                                                       | 1,120 |
| Maple, Oregon (Acer macrophyllum).             | Washington.....              | 12                        |                        | 8.3                          | .50                                                       | 34 7,600                         | 12,000                                                  | 1,580                                        |                                                       | 1.93                                           | 7.6                                           |                                                |                                                         | 30                                                  | 6,370                                                              | 7,180                                                   | 1,120                                               | 2,010                                                    | 520                                                                          | 1,630                                                                                       | 950   |
| Maple, red (Acer rubrum) consin.               | Pennsylvania, Wisconsin..... | 14                        | 24                     | 10.1                         | .54                                                       | 37 9,200                         | 14,200                                                  | 1,740                                        |                                                       | 2.80                                           | 12.8                                          | 17,000                                         | 8.2                                                     | 31                                                  | 5,430                                                              | 7,330                                                   | 1,280                                               | 1,970                                                    | 660                                                                          | 1,530                                                                                       | 990   |

| Maple, silver (Acer saccharinum).              | Wisconsin.                               | 7  | 8.2   | 0.48 | 32 | 7,700  | 10,100 | 1,210 | 2.67 | 7.615,000  | 9.4   | 24    | 5,600 | 6,600  | 1,180 | 1,710 | 490   | 1,380 | 750   |
|------------------------------------------------|------------------------------------------|----|-------|------|----|--------|--------|-------|------|------------|-------|-------|-------|--------|-------|-------|-------|-------|-------|
| Maple, sugar (Acer saccharum).                 | Indiana, Pennsylvania, Wisconsin.        | 21 | 49    | 10.5 | 43 | 10,400 | 15,800 | 1,820 | 3.52 | 13.619,100 | 9.3   | 33    | 6,060 | 8,570  | 1,620 | 2,450 | 770   | 2,000 | 1,430 |
| Oak, bur (Quercus macrocarpa).                 | Wisconsin.                               | 12 | 59    | 10.2 | 45 | 7,000  | 10,900 | 1,060 | 2.79 | 9.615,300  | 8.6   | 27    | 3,700 | 6,640  | 1,670 | 1,920 | 650   | 1,460 | 1,420 |
| Oak, California black (Quercus californica).   | California, Oregon.                      | 16 | 52    | 5.2  | 40 | 8,400  | 10,500 | 1,160 | 3.72 | 5.7 9,200  | 4.2   | 12    | 4,440 | 8,420  | 1,860 | 1,710 | 830   | 1,360 | 1,280 |
| Oak, canyon live (Quercus chrysolepis).        | California.                              | 13 | ..... | 5.0  | 54 | 11,900 | 14,700 | 1,810 | 4.67 | 7.814,300  | 6.7   | 32    | 8,100 | 13,360 | 2,890 | 2,740 | 1,500 | 3,360 | 3,150 |
| Oak, chestnut (Quercus prinus).                | Tennessee.                               | 23 | 50    | 9.5  | 46 | 10,600 | 15,000 | 1,640 | 3.55 | 11.521,200 | 9.0   | 42    | 5,280 | 7,849  | 1,180 | 1,600 | 1,510 | 1,340 | 1,200 |
| Oak, oow (Quercus michauxii).                  | Louisiana.                               | 12 | 58    | 11.3 | 47 | 7,500  | 14,500 | 1,810 | 1.75 | 11.919,200 | 8.1   | 41    | 4,420 | 7,580  | 1,420 | 2,190 | 700   | 1,310 | 1,260 |
| Oak, laurel (Quercus laurifolia).              | .....do.                                 | 11 | 61    | 9.5  | 44 | 8,700  | 14,000 | 1,770 | 2.47 | 12.015,200 | 5.9   | 39    | 5,280 | 8,230  | 1,490 | 2,030 | 790   | 1,280 | 1,260 |
| Oak, Pacific post (Quercus garryana).          | Oregon.                                  | 16 | 49    | 6.6  | 51 | 7,800  | 11,700 | 1,270 | 2.73 | 8.512,700  | 5.7   | 23    | 5,020 | 8,570  | 2,560 | 2,210 | 810   | 2,090 | 1,780 |
| Oak, post (Quercus minor).                     | Arkansas, Louisiana.                     | 26 | 54    | 11.2 | 47 | 7,800  | 13,600 | 1,540 | 2.24 | 13.317,800 | 8.6   | 46    | 3,960 | 6,890  | 1,900 | 1,900 | 780   | 1,360 | 1,390 |
| Oak, red (Quercus rubra).                      | Arkansas, Louisiana, Indiana, Tennessee. | 11 | 62    | 10.9 | 44 | 8,600  | 14,200 | 1,870 | 2.32 | 13.318,500 | 9.1   | 39    | 4,610 | 7,370  | 1,210 | 1,760 | 780   | 1,500 | 1,310 |
| Oak, Spanish (highland) (Quercus digitata).    | .....do.                                 | 20 | 46    | 10.1 | 41 | 6,400  | 11,800 | 1,560 | 1.55 | 9.716,500  | 8.3   | 26    | 3,030 | 6,800  | 1,180 | 1,530 | 520   | 1,050 | 1,100 |
| Oak, Spanish (lowland) (Quercus pagodaefolia). | .....do.                                 | 7  | 63    | 10.0 | 47 | 12,000 | 19,400 | 2,360 | 3.45 | 18.825,200 | 13.2  | 49    | 7,010 | 9,720  | 1,730 | 2,170 | 860   | 1,640 | 1,540 |
| Oak, water (Quercus nigra).                    | .....do.                                 | 10 | 61    | 10.8 | 44 | 9,200  | 16,000 | 2,060 | 2.36 | 22.619,400 | 8.6   | 44    | 3,930 | 7,200  | 1,320 | 2,010 | 940   | 1,450 | 1,220 |
| Oak, white (Quercus alba).                     | Arkansas, Louisiana, Indiana.            | 17 | 60    | 11.5 | 48 | 8,300  | 15,200 | 1,780 | 2.31 | 14.817,200 | 7.6   | 38    | 4,350 | 7,610  | 1,340 | 2,090 | 800   | 1,540 | 1,370 |
| Oak, willow (Quercus phellos).                 | .....do.                                 | 14 | 56    | 9.8  | 49 | 10,700 | 16,400 | 2,040 | 3.18 | 16.017,500 | 9.3   | 44    | 4,910 | 8,230  | 1,640 | 1,800 | 1,430 | 1,530 | 1,620 |
| Oak, yellow (Quercus velutina).                | Arkansas, Wisconsin.                     | 14 | 62    | 11.6 | 42 | 8,000  | 14,100 | 1,650 | 2.18 | 13.714,400 | 6.4   | 41    | 4,780 | 6,660  | 1,160 | 1,970 | 820   | 1,400 | 1,210 |
| Persimmon (Diospyros virginiana).              | Missouri.                                | 14 | ..... | 5.5  | 53 | 15,400 | 23,700 | 2,460 | 5.70 | 16.922,400 | 11.7  | 35    | 9,210 | 14,050 | 3,910 | 2,670 | 1,520 | 3,730 | 3,180 |
| Poplar, yellow (Liriodendron tulipifera).      | Tennessee.                               | 14 | ..... | 6.1  | 27 | 8,400  | 11,800 | 1,610 | 2.52 | 7.518,600  | 8.9   | 22    | 4,470 | 7,480  | 740   | 1,170 | 570   | 590   | 450   |
| Rhododendron, great (Rhododendron maximum).    | .....do.                                 | 28 | ..... | 4.6  | 41 | 8,400  | 14,400 | 1,270 | 3.09 | 12.5 9,200 | 3.3   | 16    | 5,510 | 9,360  | 1,920 | ..... | 890   | ..... | ..... |
| Sassafras (Sassafras sassafras).               | .....do.                                 | 19 | 48    | 6.8  | 31 | 7,700  | 10,600 | 1,220 | 2.71 | 9.511,700  | 6.1   | 31    | 3,740 | 6,060  | 1,470 | 1,380 | 620   | 670   | 600   |
| Serviceberry (Amelanchier canadensis).         | .....do.                                 | 19 | ..... | 8.4  | 52 | 13,400 | 20,000 | 1,960 | 4.88 | 19.824,500 | 12.3  | 58    | 8,640 | 11,020 | 2,300 | 1,720 | ..... | 2,490 | 2,030 |
| Silverbell-tree (Mohrodendrum carolinum).      | .....do.                                 | 20 | ..... | 6.1  | 31 | 7,300  | 9,800  | 1,400 | 2.22 | 6.216,000  | 8.0   | 23    | 4,330 | 6,890  | 860   | 1,310 | 480   | 1,060 | 650   |
| Sourwood (Oxydendrum arboreum).                | .....do.                                 | 24 | ..... | 6.8  | 38 | 10,900 | 13,800 | 1,640 | 3.87 | 11.420,700 | 11.5  | 38    | 5,600 | 8,190  | 1,370 | 1,680 | 450   | 1,680 | 1,060 |
| Sunac, staghorn (Rhus hirta).                  | Wisconsin.                               | 9  | 61    | 8.0  | 32 | 10,400 | 12,100 | 1,350 | 4.50 | 7.8        | ..... | ..... | 5,600 | 7,750  | 1,370 | ..... | ..... | 960   | 720   |

TABLE 2.—Results of tests on 146 species of wood tested in an air-dry condition in the form of small clear pieces—Continued.

| Common and botanical name.                     | Locality where grown    | Number of rings per inch. | Summerwood (per cent). | Moisture content, per cent. | Specific gravity, oven dry, based on weight per cubic foot (air dry). | Static bending.                                         |                                              |                                                       |                                                |                                               |                                               | Impact bending.                                         |                                                     |                                                                    |                                                         | Compression parallel to grain.                      |                                                                                            | Shearing strength parallel to the grain (pounds per square inch). | Tension perpendicular to grain (pounds per square inch). | Hardness, load required to imbed a 0.44-inch ball to one-half its diameter. |       |
|------------------------------------------------|-------------------------|---------------------------|------------------------|-----------------------------|-----------------------------------------------------------------------|---------------------------------------------------------|----------------------------------------------|-------------------------------------------------------|------------------------------------------------|-----------------------------------------------|-----------------------------------------------|---------------------------------------------------------|-----------------------------------------------------|--------------------------------------------------------------------|---------------------------------------------------------|-----------------------------------------------------|--------------------------------------------------------------------------------------------|-------------------------------------------------------------------|----------------------------------------------------------|-----------------------------------------------------------------------------|-------|
|                                                |                         |                           |                        |                             |                                                                       | Fiber stress at elastic limit (pounds per square inch). | Modulus of rupture (pounds per square inch). | Modulus of elasticity (1,000 pounds per square inch). | To elastic limit (inch-pounds per cubic inch). | To maximum load (inch-pounds per cubic inch). | Work in bending—(inch-pounds per cubic inch). | Fiber stress at elastic limit (pounds per square inch). | Work to elastic limit (inch-pounds per cubic inch). | Height of drop causing complete failure, 50-pound hammer (inches). | Fiber stress at elastic limit (pounds per square inch). | Maximum crushing strength (pounds per square inch). | Compression perpendicular to grain—fiber stress at elastic limit (pounds per square inch). |                                                                   |                                                          |                                                                             |       |
| 1                                              | 2                       | 3                         | 4                      | 5                           | 6                                                                     | 7                                                       | 8                                            | 9                                                     | 10                                             | 11                                            | 12                                            | 13                                                      | 14                                                  | 15                                                                 | 16                                                      | 17                                                  | 18                                                                                         | 19                                                                | 20                                                       | 21                                                                          | 22    |
| HARDWOODS—cont'd.                              |                         |                           |                        |                             |                                                                       |                                                         |                                              |                                                       |                                                |                                               |                                               |                                                         |                                                     |                                                                    |                                                         |                                                     |                                                                                            |                                                                   |                                                          |                                                                             |       |
| Sugarberry (Celtis missillipiensis).           | Missouri.....           | 17                        | 38                     | 5.0                         | 0.54                                                                  | 35                                                      | 9,500                                        | 13,000                                                | 1,410                                          | 4.23                                          | 10,714,100                                    |                                                         | 7.4                                                 | 37                                                                 | 5,960                                                   | 8,450                                               | 2,010                                                                                      | 1,450                                                             | 700                                                      | 1,640                                                                       | 1,110 |
| Sycamore (Platanus occidentalis).              | Indiana, Tennessee....  | 16                        | 77                     | 9.2                         | .50                                                                   | 34                                                      | 7,600                                        | 11,300                                                | 1,510                                          | 2.20                                          | 9,210,800                                     |                                                         | 4.0                                                 | 28                                                                 | 4,260                                                   | 6,290                                               | 1,010                                                                                      | 1,460                                                             | 750                                                      | 970                                                                         | 810   |
| Umbrella, Fraser (Magnolia fraseri).           | Tennessee.....          | 15                        | .....                  | 6.4                         | .47                                                                   | 31                                                      | 9,300                                        | 12,700                                                | 1,520                                          | 3.27                                          | 10,916,400                                    |                                                         | 7.4                                                 | 28                                                                 | 5,220                                                   | 7,500                                               | 840                                                                                        | 1,340                                                             | 790                                                      | 990                                                                         | 690   |
| Walnut, black (Juglans nigra).                 | Kentucky.....           | 12                        | .....                  | 4.8                         | .57                                                                   | 37                                                      | 14,500                                       | 17,900                                                | 1,820                                          | 6.43                                          | 9,219,400                                     |                                                         | 11.3                                                | 33                                                                 | 7,880                                                   | 10,600                                              | 1,900                                                                                      | 1,480                                                             | 780                                                      | 1,110                                                                       | 1,080 |
| Willow, black (Salix nigra).                   | Wisconsin, Missouri.... | 5                         | .....                  | 6.4                         | .38                                                                   | 26                                                      | 5,600                                        | 7,000                                                 | 830                                            | 2.45                                          | 6,8                                           | 9,200                                                   | 4.8                                                 | 16                                                                 | 2,880                                                   | 5,030                                               | 710                                                                                        | 1,340                                                             | 470                                                      | 680                                                                         | 500   |
| Willow, western black (Salix lasioandra).      | Oregon.....             | 5                         | .....                  | 4.0                         | .47                                                                   | 31                                                      | 8,000                                        | 11,100                                                | 1,540                                          | 2.39                                          | 8,413,900                                     |                                                         | 7.1                                                 | 30                                                                 | 5,000                                                   | 7,120                                               | 920                                                                                        | 1,410                                                             | 660                                                      | 1,230                                                                       | 730   |
| Witch hazel (Hamamelis virginiana).            | Tennessee.....          | 14                        | .....                  | 5.1                         | .65                                                                   | 43                                                      | 12,000                                       | 20,300                                                | 1,660                                          | 4.85                                          | 21.8                                          |                                                         |                                                     |                                                                    | 6,440                                                   | 8,430                                               | 2,170                                                                                      |                                                                   | 2,560                                                    | 1,940                                                                       |       |
| CONIFERS.                                      |                         |                           |                        |                             |                                                                       |                                                         |                                              |                                                       |                                                |                                               |                                               |                                                         |                                                     |                                                                    |                                                         |                                                     |                                                                                            |                                                                   |                                                          |                                                                             |       |
| Cedar, incense (Libocedrus decurrens).         | California, Oregon....  | 17                        | 30                     | 5.1                         | .36                                                                   | 24                                                      | 7,400                                        | 9,400                                                 | 1,300                                          | 2.31                                          | 4,911,100                                     |                                                         | 5.2                                                 | 17                                                                 | 6,400                                                   | 7,200                                               | 840                                                                                        | 900                                                               | 270                                                      | 1,040                                                                       | 520   |
| Cedar, Port Orford (Chamaecyparis lawsoniana). | Oregon.....             | 24                        | 25                     | 9.0                         | .45                                                                   | 31                                                      | 8,900                                        | 14,500                                                | 2,040                                          | 2.25                                          | .....                                         | 17,600                                                  | 7.2                                                 | 39                                                                 | 7,700                                                   | 7,750                                               | 1,020                                                                                      | 1,500                                                             | 630                                                      | 930                                                                         | 700   |



|                                              |                                  |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
|----------------------------------------------|----------------------------------|------|------|----|---------|---------|--------|------|------|---------|------|----|---------|---------|--------|--------|-------|--------|--------|
| 20                                           | 30                               | 7.4  | 0.34 | 22 | 6, 100  | 8, 800  | 1, 250 | 1.68 | 6.4  | 9, 600  | 3.4  | 16 | 45, 300 | 6, 320  | 700    | 920    | 180   | 750    | 380    |
| cedar, western red (Thuja plicata).          | Washington, Montana.             |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 23                                           | 36                               | 11.2 | .31  | 22 | 5, 100  | 6, 700  | 810    | 1.84 | 4.7  | 7, 200  | 2.8  | 12 | 2, 840  | 44, 140 | 390    | 900    | 240   | 470    | 340    |
| cedar, white (Thuja occidentalis).           | Wisconsin.....                   |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 16                                           | 31                               | 9.0  | .44  | 30 | 8, 700  | 11, 300 | 1, 540 | 3.03 | 7.3  | 11, 200 | 4.7  | 26 | 5, 970  | 7, 690  | 910    | 1, 080 | 290   | 800    | 550    |
| ypress, bald (Taxodium distichum).           | Louisiana, Missouri...           |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 31                                           | .....                            | 5.5  | .43  | 28 | 9, 000  | 12, 800 | 1, 430 | 3.37 | 8.5  | 14, 600 | 7.9  | 29 | 7, 780  | 8, 080  | 900    | 1, 120 | 430   | 810    | 580    |
| ypress, yellow (Chamaecyparis nootkatensis). | Oregon.....                      |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| onglas fir (Pseudotsuga taxifolia).          | Montana, Wyoming...              |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 22                                           | 27                               | 9.4  | .44  | 30 | 6, 900  | 10, 300 | 1, 460 | 1.83 | 6.5  | 13, 300 | 5.6  | 28 | 5, 320  | 7, 090  | 950    | 1, 080 | 320   | 750    | 600    |
| Do.....                                      | Do.....                          |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 13                                           | 35                               | 6.2  | .51  | 34 | 10, 000 | 14, 000 | 2, 210 | 2.94 | 8.4  | 14, 300 | 5.4  | 33 | 9, 260  | 10, 080 | 1, 220 | 1, 270 | 330   | 920    | 810    |
| Alpine (Abies lasiocarpa).                   | Washington, Oregon...            |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 15                                           | 14                               | 15.9 | .32  | 23 | 4, 800  | 6, 000  | 890    | 1.73 | 3.4  | 6, 700  | 2.1  | 14 | 3, 270  | 3, 400  | 500    | 1, 010 | ..... | 420    | 340    |
| Do.....                                      | Colorado.....                    |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 12                                           | 26                               | 9.3  | .39  | 27 | 7, 000  | 10, 600 | 1, 600 | 1.73 | 10.3 | 11, 900 | 5.3  | 24 | 5, 070  | 6, 540  | 580    | 1, 180 | 290   | 720    | 470    |
| ir amabilis (Abies amabilis).                | Washington.....                  |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 12                                           | 26                               | 4.8  | .38  | 25 | 7, 300  | 9, 900  | 1, 440 | 2.11 | 5.4  | 8, 500  | 2.9  | 23 | .....   | 6, 640  | 530    | 790    | 180   | 740    | 500    |
| ir, balsam (Abies balsamea).                 | Wisconsin.....                   |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 18                                           | 30                               | 6.8  | .41  | 27 | 7, 100  | 11, 000 | 1, 790 | 1.66 | 8.3  | 14, 000 | 5.8  | 32 | 5, 970  | 7, 060  | 830    | 1, 000 | 190   | 820    | 560    |
| ir, grand (Abies grandis).                   | Montana, Oregon.....             |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 13                                           | 17                               | 8.4  | .39  | 26 | 7, 000  | 10, 000 | 1, 750 | 1.92 | 9.4  | 12, 300 | 4.6  | 27 | 4, 120  | 7, 240  | 850    | 1, 090 | 130   | 860    | 470    |
| ir, noble (Abies nobilis).                   | Oregon.....                      |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 20                                           | 30                               | 9.6  | .38  | 25 | 7, 000  | 9, 800  | 1, 490 | 1.86 | 5.5  | 8, 400  | 3.2  | 14 | 4, 180  | 6, 150  | 720    | 1, 060 | 260   | 780    | 460    |
| ir, white (Abies concolor).                  | California.....                  |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 23                                           | 45                               | 8.0  | .46  | 31 | 7, 400  | 11, 400 | 1, 180 | 2.74 | 9.1  | 15, 600 | 7.9  | 36 | 4, 360  | 7, 510  | 1, 420 | 1, 260 | 340   | 1, 290 | 690    |
| emlock, black (Tsuga mertensiana).           | Montana.....                     |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 20                                           | 34                               | 8.6  | .42  | 28 | 7, 200  | 9, 700  | 1, 300 | 2.32 | 5.8  | 12, 500 | 6.0  | 24 | 5, 240  | 7, 000  | 1, 060 | 1, 160 | 190   | 800    | 490    |
| emlock (eastern) (Tsuga canadensis).         | Tennessee, Wisconsin.            |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 10                                           | 27                               | 5.4  | .42  | 28 | 8, 000  | 10, 800 | 1, 520 | 2.48 | 6.1  | 13, 000 | 6.0  | 26 | 7, 780  | 7, 910  | 830    | 1, 170 | 170   | 1, 020 | 620    |
| emlock (western) (Tsuga heterophylla).       | Washington.....                  |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 36                                           | 37                               | 8.3  | .54  | 36 | 10, 100 | 13, 500 | 1, 830 | 3.06 | 8.2  | 17, 000 | 8.6  | 34 | 8, 420  | 9, 640  | 1, 280 | 1, 530 | 340   | 1, 380 | 870    |
| arch, western (Larix occidentalis).          | Montana, Washington.             |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 17                                           | 44                               | 8.8  | .66  | 45 | 12, 400 | 18, 300 | 2, 220 | 3.88 | 13.1 | 18, 000 | 7.2  | 42 | 9, 160  | 11, 890 | 1, 620 | 1, 920 | 650   | 1, 200 | 1, 160 |
| ine, Cuban (Pinus betophylla).               | Florida.....                     |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 7                                            | 30                               | 6.1  | .44  | 29 | 6, 500  | 9, 700  | 1, 400 | 1.81 | 5.1  | 13, 100 | 5.6  | 37 | .....   | 7, 770  | 1, 150 | 1, 330 | 440   | 870    | 740    |
| ine, jack (Pinus divaricata).                | Wisconsin.....                   |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 18                                           | 23                               | 8.7  | .41  | 28 | 8, 800  | 10, 900 | 1, 310 | 3.42 | 7.1  | 14, 200 | 6.2  | 29 | 5, 200  | 6, 980  | 1, 000 | 1, 450 | 410   | 740    | 550    |
| ine, Jeffrey (Pinus jeffreyi).               | California.....                  |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 9                                            | 42                               | 6.5  | .57  | 38 | 11, 700 | 15, 600 | 2, 130 | 3.70 | 9.0  | 14, 800 | 5.9  | 26 | 7, 980  | 11, 300 | 1, 600 | 1, 720 | 370   | 1, 030 | 840    |
| ine, loblolly (Pinus taeda).                 | Florida.....                     |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 24                                           | 22                               | 7.1  | .43  | 28 | 9, 000  | 11, 500 | 1, 460 | 3.24 | 7.6  | 10, 800 | 4.7  | 20 | 6, 270  | 7, 300  | 1, 120 | 980    | 380   | 640    | 500    |
| ine, lodgepole (Pinus contorta).             | Colorado, Montana, Wyoming.      |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 18                                           | 38                               | 9.2  | .66  | 42 | 11, 800 | 16, 700 | 2, 200 | 3.58 | 11.3 | 16, 400 | 6.6  | 32 | 9, 250  | 10, 880 | 1, 670 | 1, 640 | 420   | 1, 140 | 1, 020 |
| ine, longleaf (Pinus palustris).             | Florida, Louisiana, Mississippi. |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 22                                           | 41                               | 12.5 | .48  | 34 | 9, 200  | 12, 300 | 1, 790 | 2.68 | 9.9  | 15, 100 | 6.3  | 25 | 5, 660  | 7, 080  | 830    | 1, 260 | 470   | 700    | 600    |
| ine, Norway (Pinus resinosa).                | Wisconsin.....                   |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 12                                           | 30                               | 7.6  | .52  | 35 | 7, 800  | 12, 400 | 1, 500 | 2.56 | 8.7  | 17, 200 | 10.7 | 28 | 4, 490  | 7, 600  | 1, 170 | 1, 670 | 580   | 820    | 690    |
| ine, pitch (Pinus rigida).                   | Tennessee.....                   |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 13                                           | 35                               | 6.2  | .56  | 37 | 11, 300 | 14, 600 | 2, 050 | 3.43 | 9.2  | 15, 700 | 6.3  | 26 | 8, 220  | 10, 090 | 1, 550 | 1, 720 | 410   | 1, 020 | 860    |
| ine, pond (Pinus serotina).                  | Florida.....                     |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 10                                           | 40                               | 11.0 | .54  | 38 | 9, 200  | 13, 900 | 1, 970 | 2.46 | 10.1 | 16, 000 | 6.5  | 36 | 7, 080  | 8, 660  | 1, 310 | 1, 390 | 410   | 940    | 880    |
| ine, shortleaf (Pinus echinata).             | Arkansas, Louisiana.             |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| ine, sugar (Pinus lambertiana).              | California.....                  |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 12                                           | 34                               | 11.4 | .37  | 26 | 6, 400  | 8, 600  | 1, 210 | 1.79 | 5.0  | 10, 100 | 4.3  | 17 | 4, 740  | 5, 190  | 640    | 1, 080 | 350   | 650    | 460    |
| ine, table-mountain (Pinus pungens).         | Tennessee.....                   |      |      |    |         |         |        |      |      |         |      |    |         |         |        |        |       |        |        |
| 15                                           | 29                               | 8.0  | .53  | 36 | 9, 400  | 13, 400 | 1, 650 | 3.06 | 8.9  | 15, 900 | 7.6  | 29 | 4, 560  | 8, 500  | 1, 530 | 1, 290 | ..... | 830    | 730    |

TABLE 2.—Results of tests on 126 species of wood tested in an air-dry condition in the form of small clear pieces—Continued.

| Common and botanical name.              | Locality where grown.                               | Number of rings per inch. | Summerwood (per cent). | Moisture content (per cent). | Specific gravity, over air dry, based on volume when air dry. | Weight per cubic foot (air dry) (pounds). | Static bending.                                         |                                              |                                                       |                                                |                                               |                                                                         | Impact bending.                               |                                                                    |                                                         |                                                     | Compression parallel to grain.                                                             |                                                                   | Tension perpendicular to grain (pounds per square inch). | Hardness, load required to imbed a 0.444-inch ball to one-half its diameter. |       |
|-----------------------------------------|-----------------------------------------------------|---------------------------|------------------------|------------------------------|---------------------------------------------------------------|-------------------------------------------|---------------------------------------------------------|----------------------------------------------|-------------------------------------------------------|------------------------------------------------|-----------------------------------------------|-------------------------------------------------------------------------|-----------------------------------------------|--------------------------------------------------------------------|---------------------------------------------------------|-----------------------------------------------------|--------------------------------------------------------------------------------------------|-------------------------------------------------------------------|----------------------------------------------------------|------------------------------------------------------------------------------|-------|
|                                         |                                                     |                           |                        |                              |                                                               |                                           | Fiber stress at elastic limit (pounds per square inch). | Modulus of rupture (pounds per square inch). | Modulus of elasticity (1,000 pounds per square inch). | To elastic limit (inch-pounds per cubic inch). | To maximum load (inch-pounds per cubic inch). | Work in bending—fiber stress at elastic limit (pounds per square inch). | Work to failure (inch-pounds per cubic inch). | Height of drop causing complete failure, 50-pound hammer (inches). | Fiber stress at elastic limit (pounds per square inch). | Maximum crushing strength (pounds per square inch). | Compression perpendicular to grain—fiber stress at elastic limit (pounds per square inch). | Shearing strength parallel to the grain (pounds per square inch). |                                                          |                                                                              |       |
| 1                                       | 2                                                   | 3                         | 4                      | 5                            | 6                                                             | 7                                         | 8                                                       | 9                                            | 10                                                    | 11                                             | 12                                            | 13                                                                      | 14                                            | 15                                                                 | 16                                                      | 17                                                  | 18                                                                                         | 19                                                                | 20                                                       | 21                                                                           | 22    |
| CONIFERS—continued.                     |                                                     |                           |                        |                              |                                                               |                                           |                                                         |                                              |                                                       |                                                |                                               |                                                                         |                                               |                                                                    |                                                         |                                                     |                                                                                            |                                                                   |                                                          |                                                                              |       |
| Pine, western white (Pinus monticola).  | Montana.....                                        | 28                        | 33                     | 7.9                          | 0.43                                                          | .29                                       | 7,900                                                   | 11,500                                       | 1,030                                                 | 2.17                                           | 10.0                                          | 14,500                                                                  | 5.8                                           | 29                                                                 | 5,810                                                   | 7,840                                               | 810                                                                                        | 530                                                               | .....                                                    | 470                                                                          | 420   |
| Pine, western yellow (Pinus ponderosa). | Colorado, Montana, Arizona, Washington, California. | 20                        | 22                     | 10.8                         | .41                                                           | .28                                       | 6,900                                                   | 9,800                                        | 1,340                                                 | 2.13                                           | 6.4                                           | 10,000                                                                  | 4.1                                           | 10                                                                 | 4,490                                                   | 5,990                                               | 700                                                                                        | 1,100                                                             | 410                                                      | 570                                                                          | 460   |
| Pine, white (Pinus strobus).            | Wisconsin.....                                      | 16                        | 31                     | 9.9                          | .39                                                           | .27                                       | 7,000                                                   | 9,000                                        | 1,420                                                 | 2.04                                           | 6.4                                           | 9,300                                                                   | 3.3                                           | 18                                                                 | 5,070                                                   | 6,300                                               | 700                                                                                        | 1,070                                                             | 340                                                      | 610                                                                          | 470   |
| Spruce, Engelmann (Picea engelmanni).   | Colorado.....                                       | 14                        | 14                     | 14.8                         | .32                                                           | .24                                       | 4,500                                                   | 6,800                                        | 1,030                                                 | 1.06                                           | 5.4                                           | 8,300                                                                   | 3.2                                           | 15                                                                 | 2,980                                                   | 3,810                                               | 520                                                                                        | 910                                                               | .....                                                    | 390                                                                          | 290   |
| Spruce, red (Picea rubens).             | New Hampshire, Tennessee.                           | 17                        | 32                     | 10.8                         | .41                                                           | .28                                       | 7,400                                                   | 10,800                                       | 1,550                                                 | 1.97                                           | 8.7                                           | 12,100                                                                  | 4.9                                           | 28                                                                 | 5,470                                                   | 6,380                                               | 620                                                                                        | 1,160                                                             | 380                                                      | 670                                                                          | 510   |
| Spruce, Sitka (Picea sitchensis).       | Washington.....                                     | 9                         | 24                     | 8.9                          | .38                                                           | .20                                       | 7,200                                                   | 11,200                                       | 1,610                                                 | 1.78                                           | 10.4                                          | 13,900                                                                  | 5.2                                           | 25                                                                 | .....                                                   | 5,770                                               | 1,010                                                                                      | 1,210                                                             | .....                                                    | 780                                                                          | 530   |
| Spruce, white (Picea canadensis).       | New Hampshire, Wisconsin.                           | 14                        | 27                     | 9.6                          | .40                                                           | .28                                       | 5,900                                                   | 9,200                                        | 1,390                                                 | 1.40                                           | 8.2                                           | 9,700                                                                   | 3.5                                           | 20                                                                 | 4,620                                                   | 6,020                                               | 590                                                                                        | 970                                                               | 350                                                      | 700                                                                          | 500   |
| Tamarack (Larix laricina).              | Wisconsin.....                                      | 20                        | 38                     | 11.0                         | .53                                                           | .37                                       | 8,400                                                   | 12,000                                       | 1,680                                                 | 2.35                                           | 7.1                                           | 13,000                                                                  | 5.7                                           | 23                                                                 | 5,150                                                   | 7,590                                               | 1,080                                                                                      | 1,370                                                             | 410                                                      | 720                                                                          | 640   |
| Yew, western (Taxus brevifolia).        | Washington.....                                     | 27                        | .....                  | 9.2                          | .63                                                           | .43                                       | 10,100                                                  | 16,800                                       | 1,460                                                 | 3.94                                           | 18.4                                          | 11,900                                                                  | 5.3                                           | 30                                                                 | 4,720                                                   | 9,220                                               | 2,680                                                                                      | 2,480                                                             | 410                                                      | 2,330                                                                        | 1,800 |

TABLE 3.—Approximate figures for change of properties with change of moisture content; variation of properties with specific gravity; reliability of averages, and probable deviations from averages of individual trees and specimens. For use with Tables 1 and 2.

| Property.                                                             | Average increase (or decrease) in value effected by raising (or lowering) the moisture content 1 per cent when at about 12 per cent. (See p. 18.) | Approximate power of specific gravity according to which property varies. (See p. 18.) | Probable variation of present average (when from 5 trees) from true species average. (See p. 19.) | Probable variation of random tree from average for species. (See p. 19.) |
|-----------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|
| 1                                                                     | 2                                                                                                                                                 | 3                                                                                      | 4                                                                                                 | 5                                                                        |
| Specific gravity based on volume when green.....                      | Per cent.                                                                                                                                         |                                                                                        | Per cent.<br>1.7                                                                                  | Per cent.<br>3.8                                                         |
| Weight per cubic foot <sup>1</sup> .....                              |                                                                                                                                                   |                                                                                        |                                                                                                   |                                                                          |
| Shrinkage <sup>2</sup> .....                                          |                                                                                                                                                   | 1                                                                                      |                                                                                                   |                                                                          |
| Static bending:                                                       |                                                                                                                                                   |                                                                                        |                                                                                                   |                                                                          |
| Fiber stress at elastic limit.....                                    | 6                                                                                                                                                 | 1                                                                                      | 5                                                                                                 | 12                                                                       |
| Modulus of rupture.....                                               | 4                                                                                                                                                 | 1                                                                                      | 4                                                                                                 | 9                                                                        |
| Modulus of elasticity.....                                            | 2                                                                                                                                                 | 1                                                                                      | 5                                                                                                 | 11                                                                       |
| Work to elastic limit.....                                            | 8                                                                                                                                                 | 2                                                                                      | 7                                                                                                 | 16                                                                       |
| Work to maximum load.....                                             | <sup>3</sup> -1                                                                                                                                   | 2                                                                                      | 6                                                                                                 | 14                                                                       |
| Impact bending:                                                       |                                                                                                                                                   |                                                                                        |                                                                                                   |                                                                          |
| Fiber stress at elastic limit.....                                    | 4                                                                                                                                                 | 1                                                                                      | 4                                                                                                 | 8                                                                        |
| Work to elastic limit.....                                            | 5                                                                                                                                                 | 2                                                                                      | 5                                                                                                 | 12                                                                       |
| Height of drop.....                                                   | -3                                                                                                                                                | 2                                                                                      | 7                                                                                                 | 15                                                                       |
| Compression parallel to grain:                                        |                                                                                                                                                   |                                                                                        |                                                                                                   |                                                                          |
| Fiber stress at elastic limit.....                                    | 5                                                                                                                                                 | 1                                                                                      | 5                                                                                                 | 12                                                                       |
| Crushing strength.....                                                | 4                                                                                                                                                 | 1                                                                                      | 4                                                                                                 | 9                                                                        |
| Compression perpendicular to grain—fiber stress at elastic limit..... | 6                                                                                                                                                 | 2                                                                                      | 6                                                                                                 | 14                                                                       |
| Hardness, end.....                                                    | 3                                                                                                                                                 | 2                                                                                      | 4                                                                                                 | 9                                                                        |
| Hardness, side.....                                                   | 1                                                                                                                                                 | 2                                                                                      | 5                                                                                                 | 10                                                                       |
| Shearing strength parallel to grain.....                              | 4                                                                                                                                                 | 1                                                                                      | 3                                                                                                 | 7                                                                        |
| Tension perpendicular to grain.....                                   | 1                                                                                                                                                 | 2                                                                                      | 5                                                                                                 | 12                                                                       |

<sup>1</sup> See explanation, p. 11.      <sup>2</sup> See explanation, p. 12.      <sup>3</sup> The minus sign indicates decrease.



LIST OF PUBLICATIONS AND PAPERS DEALING WITH THE  
MECHANICAL PROPERTIES OF TIMBER.

## 1. GOVERNMENT PUBLICATIONS.

|                                                                                                                                    | Date of<br>issue. |
|------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| Red Gum, with Discussion of Mechanical Properties of Red Gum Wood, Forest Service Bulletin 58. 15 cents.....                       | 1905              |
| Holding Force of Railroad Spikes in Wooden Ties, Forest Service Circular 46. 5 cents.....                                          | 1906              |
| Effect of Moisture on Strength and Stiffness of Wood, Forest Service Bulletin 70. 15 cents.....                                    | 1906              |
| *Tests of Vehicle and Implements Woods, Forest Service Circular 142. 5 cents..                                                     | 1908              |
| *Properties and Uses of Southern Pines, Forest Service Circular 164. 5 cents..                                                     | 1909              |
| The Commercial Hickories, Forest Service Bulletin 80. 15 cents.....                                                                | 1910              |
| Properties and Uses of Douglas Fir, Forest Service Bulletin 88. 15 cents.....                                                      | 1911              |
| Uses of Commercial Woods of United States—Cedars, Cypressess, and Sequoias, Forest Service Bulletin 95. 10 cents.....              | 1911              |
| Uses of Commercial Woods of United States—Pines, Forest Service Bulletin 99. 15 cents.....                                         | 1911              |
| Manufacture and Utilization of Hickory, Forest Service Circular 187. 5 cents..                                                     | 1911              |
| Tests of Structural Timbers, Forest Service Bulletin 108. 20 cents.....                                                            | 1912              |
| Fire-Killed Douglas Fir: A Study of Its Rate of Deterioration, Usability, and Strength, Forest Service Bulletin 112. 10 cents..... | 1912              |
| Strength Values for Structural Timbers, Forest Service Circular 189. 5 cents..                                                     | 1912              |
| Mechanical Properties of Redwood, Forest Service Circular 193. 5 cents.....                                                        | 1912              |
| *Strength Tests of Cross-Arms, Forest Service Circular 204. 5 cents.....                                                           | 1912              |
| Mechanical Properties of Western Hemlock, Forest Service Bulletin 115. 15 cents.....                                               | 1913              |
| Mechanical Properties of Western Larch, Forest Service Bulletin 122. 10 cents..                                                    | 1913              |
| Mechanical Properties of Woods Grown in United States, Forest Service Circular 213. 5 cents.....                                   | 1913              |
| Tests of Packing Boxes, Forest Service Circular 214. 5 cents.....                                                                  | 1913              |
| Uses of Commercial Woods of United States—Beech, Birches, and Maples, Department Bulletin 12. 10 cents.....                        | 1913              |
| Tests of Rocky Mountain Woods for Telephone Poles, Department Bulletin 67. 5 cents.....                                            | 1914              |
| Rocky Mountain Mine Timbers, Department Bulletin 77. 5 cents.....                                                                  | 1914              |
| Tests of Wooden Barrels, Department Bulletin 86. 5 cents.....                                                                      | 1914              |
| Strength Tests of Structural Timber Treated by Commercial Wood Preserving Processes, Department Bulletin 286. 5 cents.....         | 1915              |

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Department Bulletin 552.—“The Seasoning of Wood” is also of special interest to those handling timber. It can be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C.

NOTE.—Publications out of print can be consulted at many public libraries. In a number of cases they have been superseded by more recent publications. Others can be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at the price stated, until the supply is exhausted. Remittances should be made by money order, or in coin (at sender's risk): stamps can not be accepted.

2. PAPERS PREPARED BY FOREST PRODUCTS LABORATORY AND PUBLISHED IN PROCEEDINGS OF SOCIETIES AND TECHNICAL, TRADE, AND OTHER JOURNALS.

| Title.                                                       | Author.                          | Where published.                                                                  | Date.                     |
|--------------------------------------------------------------|----------------------------------|-----------------------------------------------------------------------------------|---------------------------|
| A Few Deductions from Strength Tests of American Woods.      | Newlin, J. A. ....               | American Lumberman. ....                                                          | Jan. 16, 1915.            |
| Factors Affecting Structural Timbers.                        | Betts, H. S. ....                | Engineering Record. ....                                                          | Aug. 29, 1914.            |
| Grading Rules of Yellow Pine Structural Timber Discussed.    | .....do.....                     | American Lumberman. ....                                                          | Apr. 24, 1915.            |
| Applicability of Yellow Pine Grading Rules to Other Timbers. | Newlin, J. A. ....               | Engineering Record. ....                                                          | Oct. 3, 1914.             |
| Air Seasoning of Timber. ....                                | Kempfer, W. H. ....              | American Railway Engineering Bulletin 161.                                        |                           |
| Effect of Different Methods of Drying on Strength of Wood.   | Tiemann, H. D. ....              | Lumber World Review. ....                                                         | Apr. 10, 1915.            |
| *Fourth Progress Report on Tests of Treated Ties.            | .....                            | American Railway Engineering and Maintenance of Way Association Bulletin 124.     |                           |
| The Protection of Ties from Mechanical Destruction.          | Weiss, H. F. ....                | Proceedings American Wood Preservers' Association.                                | 1914.                     |
| Greenheart: a Timber with Exceptional Properties.            | Armstrong, A. K. ....            | Engineering Record. ....                                                          | Jan. 29 and Feb. 5, 1916. |
| Variation in the Weight and Strength of Timber.              | Newlin, J. A. ....               | St. Louis Lumberman, American Lumberman, Southern Lumberman, Lumber World Review. |                           |
| Structural Timber in the United States.                      | Betts, H. S., and Greeley, W. B. | International Engineering Congress, San Francisco.                                | Sept. 20-25, 1915.        |

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# UNITED STATES DEPARTMENT OF AGRICULTURE



## BULLETIN No. 557



Joint Contribution from the Bureau of Plant Industry, WM. A. TAYLOR, Chief, and the Office of Markets and Rural Organization, CHARLES J. BRAND, Chief

Washington, D. C.



May 18, 1917

### A COMPARISON OF SEVERAL CLASSES OF AMERICAN WHEATS AND A CONSIDERATION OF SOME FACTORS INFLUENCING QUALITY.<sup>1</sup>

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#### INTRODUCTION.

The task of placing wheat classification and grading on a scientific basis involves a consideration of two important problems, the first of which is the investigation of the fitness of the several types of wheat for the manufacture of white flour and the adaptation of the flour from these several types to the manufacture of different kinds of bread products. This primarily concerns the division of wheats of distinctly different character into general classes.

<sup>1</sup> The investigations reported herein were made in the Office of Grain Standardization of the Bureau of Plant Industry, under the direction of Dr. J. W. T. Duvel, Crop Technologist in Charge, in cooperation with the chemical department of the North Dakota Agricultural Experiment Station. Since August 18, 1916, the grain-standardization investigations of the Department of Agriculture have been administered jointly by the Bureau of Plant Industry and the Office of Markets and Rural Organization in connection with the enforcement of the United States Grain Standards Act.

The second problem is the comparative valuation of the wheat within any one class or, in other words, the relative importance of factors usually considered in commercial grading. These factors, briefly, are soundness, general appearance, composition, moisture content, varietal differences, and impurities, especially such impurities as are difficult to remove. In this connection the relation of such determinations as weight per bushel and average weight of kernels to quality naturally forms a part of the study.

Having these problems in mind and recognizing that the only sound basis for the determination of its fitness for the manufacture of flour and a study of the characteristics of the flour produced from it, extensive investigations involving milling tests with wheat and baking tests with the flour have been carried on for several years. A partial survey of the results of this work is presented in the following pages.

## FACTORS OF IMPORTANCE IN DETERMINING THE QUALITY OF WHEAT.

### MILLING YIELD AND FLOUR COLOR.

The term "milling quality" has a varied meaning, and in speaking of wheat of high milling quality two millers may have very different standards in mind. Broadly speaking, any wheat which will yield a high percentage of white, sound flour is of good milling quality. Flour yield, or the quantity of flour of good color that can be produced from wheat, is always the most important consideration in judging wheat. Other factors are of importance in deciding the purpose for which the flour from a certain kind of wheat is best adapted, but usually play a minor part in determining values.

Flour yield and flour color, or the color of the bread produced from the flour, must always be considered together, as they are closely related in their commercial significance. Yield is the quantitative expression of the amount of flour that can be produced from wheat, while color is the chief factor in determining the grade of the flour and consequently its selling price.

Flour yields in the following pages are expressed as a percentage of straight flour. The term "straight" in this connection has much the same significance as it has commercially, and includes all of the flour usually included in the "Patent" and "Clear" grades.

The color scoring system is based on an arbitrary scale on which the highest markings are 105, but only very exceptional straight flours score over 100. The scoring is decided upon by comparison with loaves from check or standard flours. Straight flour from ordinary sound wheat will score usually between 90 and 100. Flour which will not score more than 50 is of such poor quality that it would be classed with the lowest grade of commercial flours, such as "red dog."

## FLOURS OF HIGH AND OF LOW STRENGTH.

The definition given for a wheat of high quality holds good only when no consideration is given to the remarkable variation in the working qualities of different flours in the hands of the baker. Strength may be defined as that quality in flour which enables the baker to produce a loaf of bread of large volume and of good texture by use of the proper ingredients, together with proper mixing, fermentation, and baking.<sup>1</sup> From this definition it will be apparent that strength is of great importance in the making of ordinary fermented bread. For other food products, however, high strength is not required and is not even desirable. This is especially true in the manufacture of products in which chemical leavening agents are used in place of yeast. Low-strength flours are preferable in the making of crackers and practically all pastry, as they yield products which are free from undesirable toughness and, on the other hand, are either flaky, brittle, or crumbly, as the character of the product demands; and this result is attained with a saving in the quantity of lard or other shortening required as compared with what is necessary for stronger flours.

In the manufacture of macaroni and similar products, although strong flours are not necessary, ordinary low-strength flours are not at all suitable. The essential requirements of wheat for making flour for these purposes are that it shall be hard in texture and of such character that it will pulverize into a coarse granular flour, or, as it is more often called, "semolina," and that this be glutenous, or high in gluten proteids. The first of these requirements seems to facilitate the mechanical part of the manufacture, while the second improves the quality of the product by preventing disintegration during cooking.

## LOAF VOLUME AND TEXTURE.

This leads to a consideration of the measure of strength in flour. The definition of strength already given mentions two factors as of importance, namely, size and texture of loaf. A measure of the volume of the loaf gives the desired information as to size, and in the following pages this is expressed in cubic centimeters. The figures are comparative, as in every case 340 grams of flour were used for a loaf. It is more difficult to express texture in absolute terms, as it is dependent upon several related considerations. The uniformity, number, and evenness of distribution of cavities are

<sup>1</sup> The term "strength" is sometimes considered as meaning the water-absorbing power of the flour, but the definition given above is the one far more widely used at the present time. Some writers use the term "pile" in referring to the shape and texture of the loaf. William Jago and W. C. Jago, in the 1911 edition of their *Technology of Bread-Making*, define strength as the measure of the capacity of the flour for producing a bold, large-volumed, well-risen loaf. In this definition the term "bold" refers to the external appearance of the loaf and "well-risen" to the texture, but the terms seem to be lacking in definiteness.



the most important points. For a loaf to be of good texture the walls of the cells should be thin and nearly transparent. To obtain a measure of texture it has been found necessary to resort to an arbitrary scoring system based on the ideal as 100.

In order to demonstrate clearly what is meant by differences in strength as indicated by loaf volume and texture, figures 1 and 2,



FIG. 1.—Loaves of bread showing a wide range in volume. The volumes in cubic centimeters are as follows: *a*, 2,700; *b*, 1,855; *c*, 2,400; *d*, 3,020; *e*, 2,170.

showing photographs of loaves having a wide range in quality, are introduced here. Figure 1 shows the exterior of loaves having a volume varying from 1,855 to 3,020 cubic centimeters. The volume of the loaves, in cubic centimeters, in order, is as follows: *a*, 2,700; *b*, 1,855; *c*, 2,400; *d*, 3,020; *e*, 2,170. Figure 2 shows another series

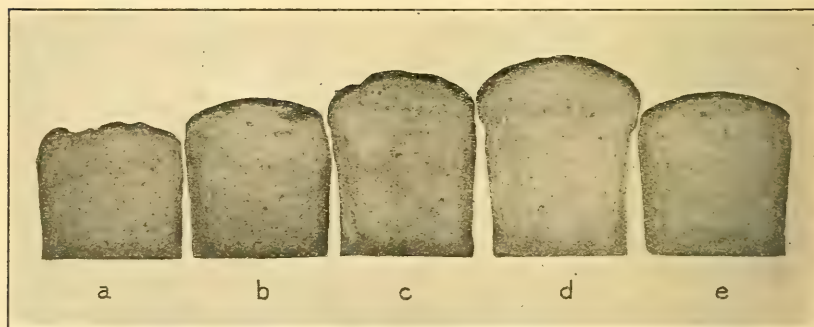


FIG. 2.—Loaves of bread showing a wide range in strength of flour, as indicated by differences in volume and texture. The volumes in cubic centimeters and the texture scores of these loaves are as follows: *a*, Volume 1,550, texture 84; *b*, volume 1,830, texture 90; *c*, volume 2,330, texture 94; *d*, volume 2,660, texture 97; *e*, volume 1,950, texture 88.

of loaves in cross section, illustrating differences in texture as well as volume. The volume of loaf *a* is 1,550 cubic centimeters and the texture 84. This is the type of loaf produced from the softest wheats and those of lowest strength. The texture is even, but the cell walls are thick and the bread is solid and heavy. Loaf *b* is a little below average strength for soft wheats, the volume being 1,830

cubic centimeters and the texture 90. The texture is uneven, a little coarse, and the cell walls are somewhat thick. Loaves *c* and *d* are of the type ordinarily produced from hard red winter and hard red spring wheats. The volume of loaf *c* is 2,330 cubic centimeters and the texture 94; it is somewhat uneven but the cell walls are fairly thin. Loaf *d* has a volume of 2,660 cubic centimeters and a texture which, although a little uneven, is scored 97, since the cell walls are very thin. Loaf *e* has a volume of 1,950 and a coarse texture, which is scored 88.

#### WATER ABSORPTION.

Capacity for water absorption is of some commercial importance and is determined by measuring the water added in mixing the dough. It is important because of its relation to the weight of the baked loaf, as will be brought out further in the following pages. It might be considered as one element in the strength of flour if the definition were changed to include, besides requirements for lightness and texture of loaf, a requirement for a high yield of bread per unit quantity of flour.

#### CLASSES OF WHEAT STUDIED.

In all, five distinct classes of wheats, grown in various sections of the United States, have been studied; but the main part of this report will be confined to the four classes to which more time has been given. The five classes are as follows:

(1) Soft red winter wheat, or "red winter," as it is better known on the market, is the principal class of wheat grown in sections east of the Mississippi River, in the State of Missouri, and in parts of the States adjoining to the west and south.

(2) Hard red winter wheat is grown chiefly in Nebraska, Kansas, and parts of Oklahoma and Montana, although small quantities are grown in the adjoining States.

(3) Hard red spring wheat is grown in North Dakota, Minnesota, South Dakota, and Montana. This wheat is more generally known commercially as northern spring wheat.

(4) Durum wheat is grown in about the same territory as hard red spring wheat and to a limited extent in the southern Great Plains area and Intermountain and Pacific Coast States.

(5) White wheats are grown to a comparatively small extent in some of the Eastern States and more generally in the Intermountain and Pacific Coast States. Only a limited amount of work was done on this class of wheats, and in this report reference will be made only to some factors relating to the quality of the flour produced from them.

There are other classes of wheats, particularly the western red wheats, both spring and fall sown, of which no mention will be made in the following pages.

## MILLING YIELD AND RELATED FACTORS.

## YIELD OF FLOUR.

As has been said, flour yield is the most important consideration in determining wheat values. Figure 3 affords a comparison of the average flour yields of soft red winter, hard red winter, hard red spring, and durum wheats, and also the extreme and ordinary ranges for each class. While an extreme range in flour yield of about 20 per cent was secured with the durum wheat and a somewhat narrower range for other classes, the ordinary ranges show a variation of only about 10 per cent. Over 90 per cent of the samples of soft red winter and hard red spring and 80 per cent of the durum samples yielded between 65 and 75 per cent of straight flour. The hard red winter samples ranged somewhat higher, as over 90 per cent yielded between 67 and 77 per cent of straight flour.

In average flour yield the hard red winter wheat is about 2 per cent higher than the other classes, between which only small dif-

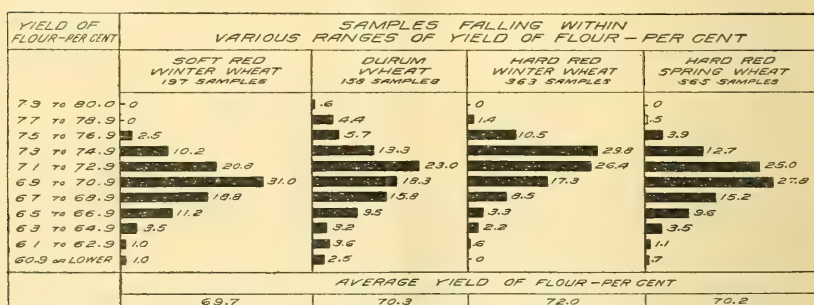


FIG. 3.—Diagram presenting a comparison of the yield of straight flour of four commercial classes of American wheat, showing their general range and the average for each class. The samples used represented the crop years from 1908 to 1913, inclusive, except those of soft red winter wheat, of which only samples of the crops of 1911, 1912, and 1913 are included.

ferences are noted, although soft red winter wheat falls slightly below the hard red spring and durum wheats. That this poor showing of the soft red winter wheat is due in part to experimental error is very probable, as this wheat is very difficult to handle in an experimental mill, the flour being soft and fluffy, clinging to the spouts to an unusual degree and causing not only a greater average mechanical loss but also greater moisture losses through evaporation. This is borne out by the figures in Table I, which shows that the average loss was 1.2 per cent greater for soft red winter wheat than for spring wheat. With durum wheat the opposite was true. Durum wheat reduced to a very coarse granular flour which showed practically no tendency to hang to the spouts and dust out.



TABLE I.—Average yield of flour, bran, and shorts of four commercial classes of American wheat and average loss in the milling process.

| Class of wheat.      | Number of samples tested. | Milling yields. |                  | Loss in milling. |
|----------------------|---------------------------|-----------------|------------------|------------------|
|                      |                           | Flour.          | Bran and shorts. |                  |
|                      |                           | <i>Per ct.</i>  | <i>Per ct.</i>   | <i>Per ct.</i>   |
| Soft red winter..... | 197                       | 69.7            | 27.1             | 3.2              |
| Durum.....           | 158                       | 70.3            | 28.9             | .8               |
| Hard red winter..... | 363                       | 72              | 26.4             | 1.6              |
| Hard red spring..... | 565                       | 70.2            | 27.8             | 2                |

It might also be mentioned that the water used in tempering probably had some influence on these figures. With soft-textured wheat like the soft red winter, owing to the tendency toward flaking or flattening out of the particles of endosperm during the grinding process when too much moisture is present, it was not desirable to use a large quantity of water in tempering or conditioning this wheat to toughen the bran previous to milling, while with durum

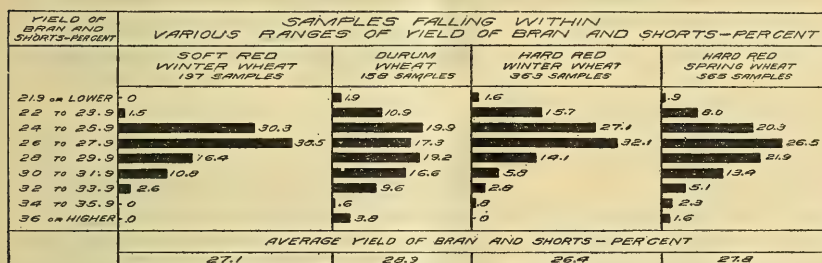


FIG. 4.—Diagram presenting a comparison of the yield of feed (bran and shorts) of four commercial classes of American wheat, showing their general range and the average for each class.

wheat, which is very hard and brittle, the moisture content was raised about 2 per cent on the average by this process. As all yields are figured on the basis of the original cleaned sample, one reason for these differences is apparent. In many cases the durum samples showed a gain in milling due to this added water, but this was very seldom shown with soft wheats.

## YIELD OF BRAN AND SHORTS.

Figure 4 is a companion to figure 3 and shows in another way the same relation of the milling quality of these four classes of wheat. The importance of a low yield of bran and shorts is evident from the direct relationship of these factors to flour yield.

## MOISTURE CONTENT AND FLOUR YIELDS.

As was brought out in the above discussion and in Table I, evaporation during the milling process bears a very important relationship to flour yield. The extent to which evaporation occurs when

factors such as humidity, exposure, and the length of the milling process are equal is dependent upon the moisture content of the wheat. This is very clearly brought out in figure 5, which shows the relation between moisture content and flour yield for each of the

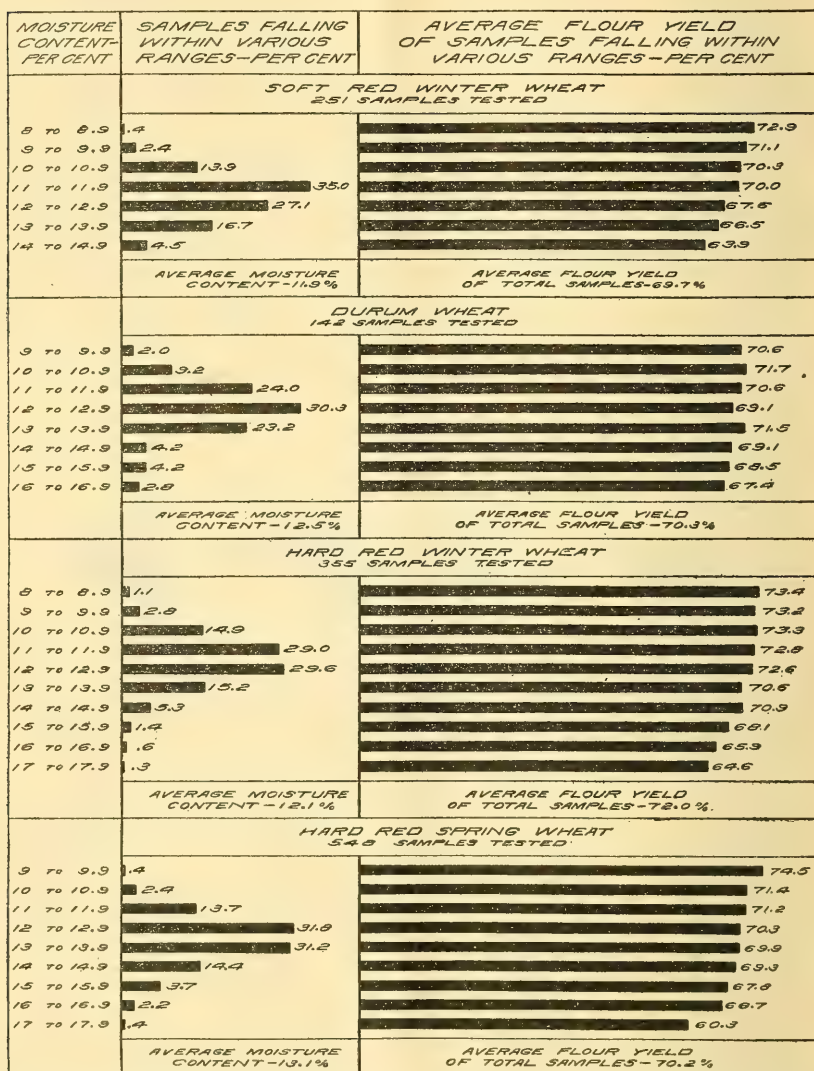


FIG. 5.—Diagram showing the variation in moisture content of the samples of four commercial classes of wheat and the relation of this factor to flour yield.

four classes of wheat under discussion, and also the extreme and the ordinary range and the average moisture content of samples representing each class. It will be noted that with each class the flour yield in a general way varies inversely as the moisture content.

Figure 6 would seem to prove the hypothesis that the reason for this relationship lies in the evaporation of moisture during the milling process. It shows that there is a very regular increase in milling loss as the moisture content increases.

#### FLOUR YIELD AND WEIGHT PER THOUSAND KERNELS.

That there might be a relationship between milling yield and average weight of kernels was suggested by several seemingly pertinent facts. Plump or well-filled kernels naturally have a higher weight than shriveled kernels, and that the former are superior in quality as far as milling yield is concerned is evident. Likewise, field damage from sprouting, leaching, and other causes tends to decrease the weight of the

kernels somewhat, and these facts bear a direct relationship to milling quality. Figure 7 presents graphically the results of the study of these two factors in relation to each other. It will be noted from this that the weight per 1,000 kernels apparently is not a very good indication of milling yield. Only in the case of badly

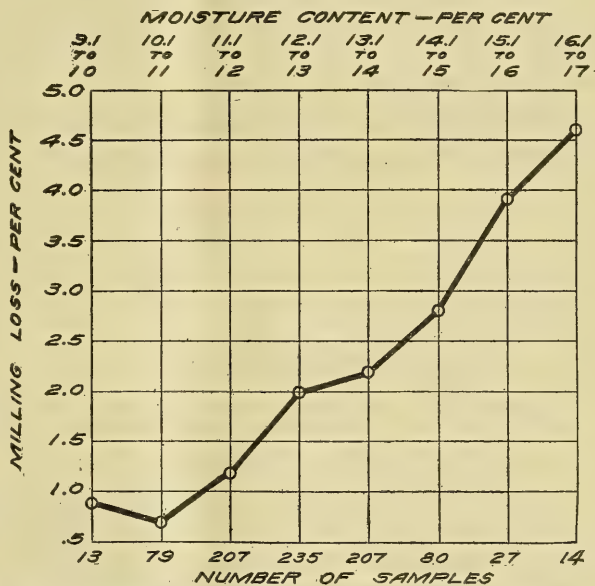


FIG. 6.—Diagram showing the relation between the loss in milling and the moisture content of the wheat.

shriveled samples having an unusually low weight does this factor parallel low flour yield. Two or three factors seem to contribute toward this result. The first and probably most important are varietal differences. Some varieties of wheat have comparatively small kernels, yet give as good a flour yield as wheat of other varieties having much larger kernels. Then, again, seasonal and general environmental conditions cause variations in the size of kernels which do not seem in all cases to be accompanied by corresponding changes in milling yield. One factor related to this is the moisture content, an increase in which also increases the weight of kernels, but this is accompanied by a decrease in flour yield.



## FLOUR YIELD AND WEIGHT PER BUSHEL.

The value of the "weight per bushel" or "test-weight" determination as a rough means of measuring wheat quality has long been recognized by the grain trade, and requirements relating thereto are made in practically all grading rules. The weight of the measured

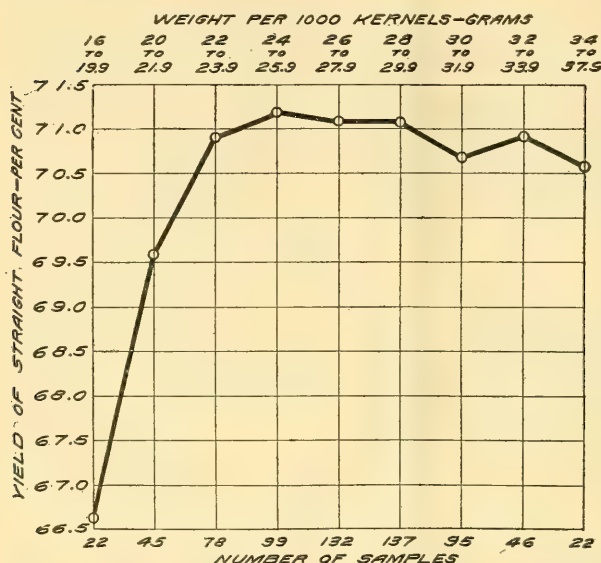


FIG. 7.—Diagram showing the relation between the weight per 1,000 kernels and the flour yield of samples of soft red and hard red winter and hard red spring wheat of the crops of 1911, 1912, and 1913.

removed. Generally, however, no such rule is observed. The determinations reported here were made with the samples after they had been cleaned and prepared for milling, and the influence of impurities is reduced to a minimum. It will be found that the figures for this reason are a little higher than those ordinarily secured.

Among the factors causing variation in the test weight are shriveled or shrunken kernels, the various forms of damage usually sustained in the field, the moisture content, and varietal differences. The last-mentioned factor is unfortunate and detracts from the value of the test rather than adds to it, as such variations often have little relation to quality. More will be said of this in a following paragraph. All the other factors mentioned bear a direct relation to quality.

That high moisture content is accompanied by low flour yields has been brought out, and as high moisture content is also accompanied by low weight per bushel it is apparent that this determination is

bushel of pure wheat is dependent upon the specific gravity, shape, size, and uniformity of the kernels. As usually determined, it is affected by impurities, such as weed seeds, dirt, chaff, and other grains. Grade rules in force in a few markets provide that the determination be made on the screened sample, or, in other words, after the larger part of the impurities have been

of value. Shriveled or shrunken wheat ordinarily gives a low flour yield, because of the low proportion of endosperm to bran and germ, and such wheat is low in weight per bushel. Field damage in various forms seems to bear a direct relation to the quality of wheat, as will be illustrated later, and usually is accompanied by a marked decrease in weight per bushel.

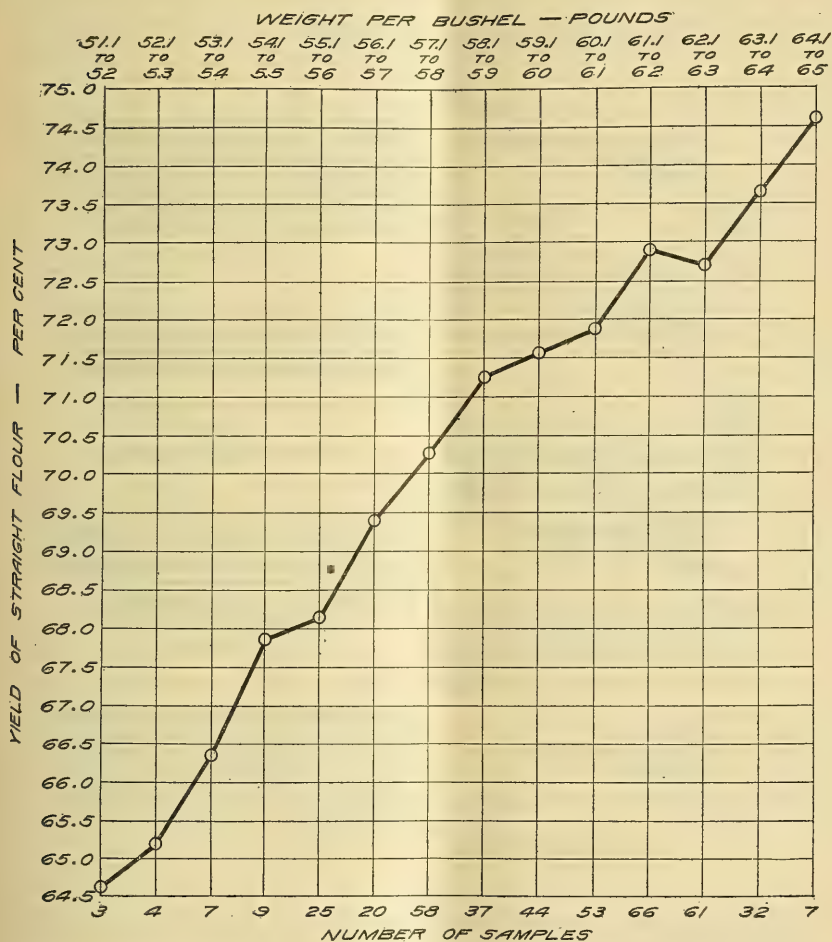


FIG. 8.—Diagram showing the relation between the milling yield and the weight per bushel, as indicated by the results of milling tests with samples of hard spring and hard winter wheat representing the crops of 1911 and 1912.

This brief statement will explain the results graphically presented in figures 8 and 9. In figure 8 are summarized the results of tests with all samples of hard wheats of the crops of 1911 and 1912. The direct relationship between weight per bushel and flour yield is so evident from this diagram that no explanation is needed. In figure 9 more complete data bearing on this relationship are presented.

This diagram shows the variation in weight per bushel of soft red winter, durum, hard red winter, and hard red spring wheats, and also the variation in flour yield for the different ranges in weight per bushel.

It will be noted from figure 9 that as between classes there seems to be little relation between weight per bushel and milling yield. To illustrate: Although the durum samples averaged highest in

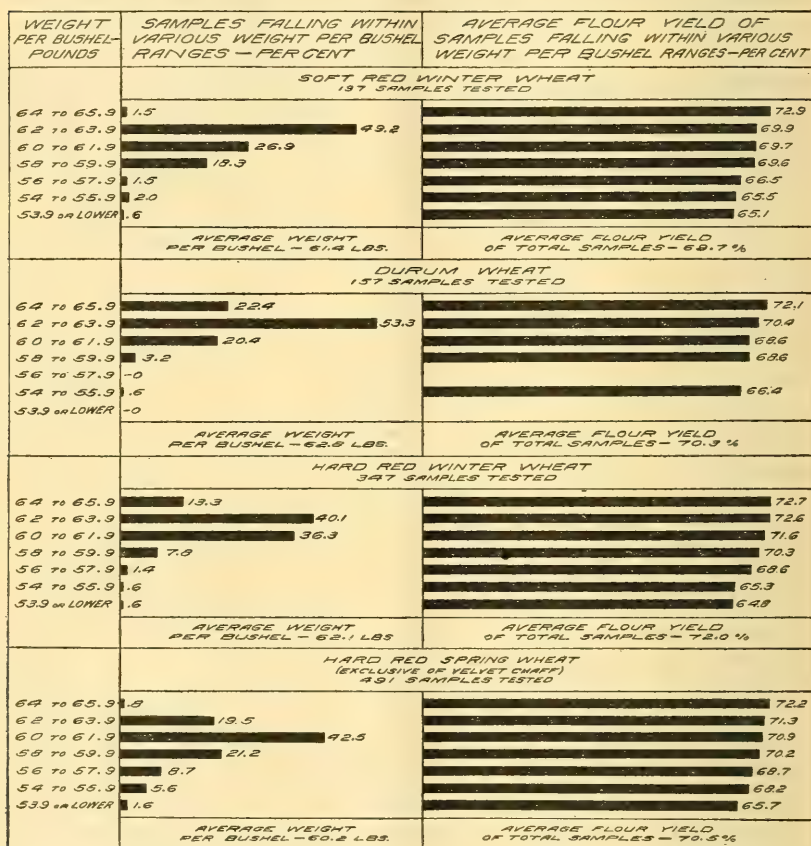


FIG. 9.—Diagram showing the relation between the weight per bushel and the flour yield of four important commercial classes of wheat. The samples represent the crops of 1908 to 1913, inclusive, except those of soft red winter wheat, of which are included samples of the crops of 1911, 1912, and 1913 only.

weight per bushel, the average flour yield is next to the lowest, and spring wheat although lowest in weight per bushel is next to the highest in average flour yield.

These variations in the relation of weight per bushel to flour yield among the several classes seem to be associated with differences in the shape, size, and density of kernels and perhaps also the thickness of the bran, any or all of which may be varietal characteristics or



the result of environment. Similar variations are found to exist to some degree within each class, and especially is this true of the hard red spring wheat. In this class there are three important varietal groups—namely, Fife, Bluestem, and Preston, or Velvet Chaff.<sup>1</sup>

While between the first two groups no marked differences are noted, the Velvet Chaff wheat, although usually having a high weight per bushel, does not show milling quality superior to the Fife and Bluestem; in fact, it seems to be somewhat inferior. Consequently, when Velvet Chaff is mixed indiscriminately with Fife and Bluestem

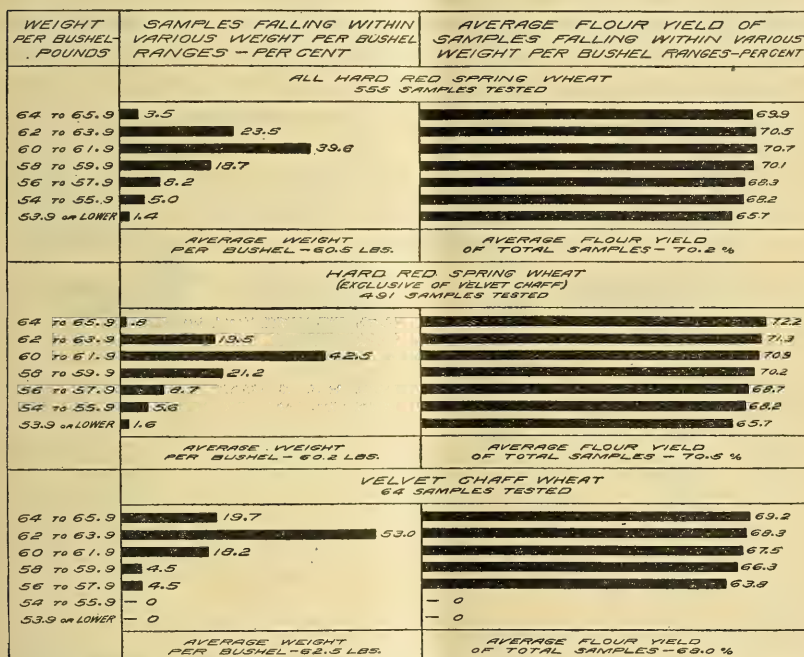


FIG. 10.—Diagram showing the relation between the weight per bushel and the flour yield of hard red spring wheat and the difference in this relation between the so-called Velvet Chaff and the wheat of other varieties. Samples from 1908 to 1913 crops, inclusive.

the weight per bushel is a precarious guide to follow. This is illustrated in figure 10. In the upper part of this diagram all hard red spring samples have been grouped, and it will be noted that there is here no definite relation of flour yield to weight per bushel. When

<sup>1</sup>The term "Velvet Chaff" as applied to this group of varieties of spring wheat is unfortunate from a botanical standpoint, because of the fact that the chaff or glumes are not velvety or pubescent. This group consists of what are supposedly a number of different varieties, many of which are thought to have originated from the Canadian wheat known as Preston. Nearly all varieties of bearded spring wheat having smooth or glabrous chaff are included. As this paper is written from the commercial standpoint, and as the entire grain trade and most farmers know this wheat as Velvet Chaff, this designation for this variety group will be adhered to in the following pages; but it should be borne in mind that the term Preston is preferable from a technical standpoint.

these samples are separated and the data compiled in a similar manner, however, the reason for this seeming inconsistency in results is apparent.

First, the high percentage of the samples of Velvet Chaff having a high test weight, as compared with the other varieties of spring wheat will be noted and then the lower average flour yield for each range in weight per bushel. These facts illustrate the necessity of care in interpreting the weight-per-bushel determination as applied to wheat of different varieties.

It should also be borne in mind that tests with individual samples do not show the same regularity as is suggested by the averages shown in these illustrations, and the test weight should in all cases be considered in conjunction with other factors, such as moisture content and soundness, of which more will be said later.

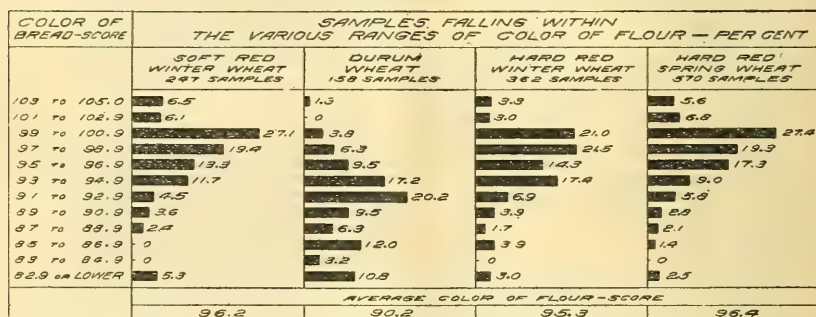


FIG. 11.—Diagram presenting a comparison of the color score of the bread made from five classes of wheat, showing variations, extreme ranges, and averages.

### COLOR OF FLOUR AND BREAD.

The importance of a consideration of the color of flour or bread made of flour in connection with milling yields has been mentioned. Commercially, because of the popular demand for white bread, flour color has come to be one of the most important considerations in buying and selling this product. The question naturally arises as to whether there is any general difference in the color of flour of the wheat of the several classes. Figure 11 presents data which will afford a fairly satisfactory answer to this question. The arrangement of this diagram gives an idea of the ordinary ranges in color of the bread from each class, and it will be observed that very little difference is apparent between the classes except in the case of durum wheat. The typical flour from this wheat varies in color from a pronounced creamy white to what might be described as pale yellow.

The comparison shown in figure 11, however, does not tell the whole story, as there are variations in color that can not be expressed by a score. For example, under this system two flours may score the

same, though one may be creamy while the other is a grayish white. In order to determine to what extent these color tints are characteristic of any one class, notes relative to them were made on all samples of the crops of 1912 and 1913. A summary of these observations is made in Table II. In this table the samples are classified under two headings, the first including all samples entirely free from creamy or yellow tints, being either pure white or grayish, and the second including samples having a distinctly creamy or yellow tint, as well as cloudy or creamy gray samples. Table II shows that all of the durum wheats fall under the second heading. In the other classes of hard wheats the creamy tints predominate to a less extent, while in the soft red wheats the pure white and gray tints predominate. Old or weathered wheat yields flour with a less pronounced creaminess, and this will account for part of the variation among the hard red wheats. There is also some varietal difference, especially among the hard red spring wheats. Bluestem and Velvet Chaff wheats usually yield flours of a pronounced creamy tint, while the Fife flour tends more toward pure white or grayish white. With the soft red winter wheat the creamy tint ordinarily is absent or not very pronounced, although some varieties seem to differ in this respect, as with other classes.

TABLE II.—*Relative dominance of various color tints of the flour of four commercial classes of wheat, samples of the crops of 1912 and 1913 being used.*

| Class of wheat.      | Number of samples. | Proportion of samples yielding flour of various color tints (per cent). |                                                    |
|----------------------|--------------------|-------------------------------------------------------------------------|----------------------------------------------------|
|                      |                    | White to gray, with no marked creamy or yellow tint.                    | Creamy to yellow (cloudy or creamy gray included). |
| Durum.....           | 49                 | —                                                                       | 100                                                |
| Hard red winter..... | 116                | 22.4                                                                    | 77.6                                               |
| Hard red spring..... | 210                | 30.5                                                                    | 69.5                                               |
| Soft red winter..... | 90                 | 81.1                                                                    | 18.9                                               |

#### RELATION OF YIELD AND COLOR TO TEST WEIGHT AND SOUNDNESS.

The unavoidable relation between flour yield and flour color in milling makes it important that the diagrams already discussed, showing the relation of flour yield to test weight, be supplemented by a study in which the color of the flour is taken into consideration. This has been done in Table III in connection with a study of the relation of these factors to soundness.

Considering only that part of Table III which relates to weight per bushel, it is apparent that although the relation of this factor to flour yield is quite evident in the diagrams previously shown, this is



not true of flour color except with wheat which is fairly low in test weight and then the color falls somewhat lower than with the heavier wheat. This holds true with all three classes of wheat with which this comparison was made.

This table is arranged to bring out such connection as may exist between the percentages of sound wheat and flour yield and color. By percentage of sound wheat is meant that portion of the sample remaining after all damaged kernels, seeds, dirt, and other grains have been removed. As in these studies the analyses were made on samples prepared for milling and after most of the impurities, such as seeds, dirt, and other grains, had been separated, the main factor to be considered is damage, other determinations averaging so low as to be almost negligible.

An analysis of Table III from this standpoint reveals a direct connection between the flour yield and the percentage of sound wheat. With all three classes there is a fairly regular decrease in flour yield as the percentage of sound wheat decreases.

TABLE III.—*Relation of weight per bushel and soundness of wheat to flour yield and color of bread in hard red spring, hard red winter, and soft red winter wheat of the crops of 1911, 1912, and 1913.*

| Class of wheat and ranges in weight per bushel (pounds). | Ranges in percentage of sound wheat. |              |                 |                    |              |                 |                    |              |                 |                    |              |                 |                    |              |                 |                    |              |                 |
|----------------------------------------------------------|--------------------------------------|--------------|-----------------|--------------------|--------------|-----------------|--------------------|--------------|-----------------|--------------------|--------------|-----------------|--------------------|--------------|-----------------|--------------------|--------------|-----------------|
|                                                          | 95 to 100.                           |              |                 | 90 to 94.9.        |              |                 | 85 to 89.9.        |              |                 | 80 to 84.9.        |              |                 | 79.9 or less.      |              |                 | Average of all.    |              |                 |
|                                                          | Number of samples.                   | Flour yield. | Color of bread. | Number of samples. | Flour yield. | Color of bread. | Number of samples. | Flour yield. | Color of bread. | Number of samples. | Flour yield. | Color of bread. | Number of samples. | Flour yield. | Color of bread. | Number of samples. | Flour yield. | Color of bread. |
|                                                          | <i>P. ct.</i>                        |              |                 | <i>P. ct.</i>      |              |                 | <i>P. ct.</i>      |              |                 | <i>P. ct.</i>      |              |                 | <i>P. ct.</i>      |              |                 | <i>P. ct.</i>      |              |                 |
| Hard red spring:                                         |                                      |              |                 |                    |              |                 |                    |              |                 |                    |              |                 |                    |              |                 |                    |              |                 |
| 64 to 65.9....                                           | 2                                    | 72           | 100             | 3                  | 73.3         | 92.3            |                    |              |                 |                    |              |                 |                    |              |                 | 5                  | 72.8         | 95.4            |
| 62 to 63.9....                                           | 35                                   | 71.5         | 98              | 12                 | 70.9         | 95.5            | 5                  | 72.2         | 97.2            |                    |              |                 |                    |              |                 | 52                 | 71.4         | 97.5            |
| 60 to 61.9....                                           | 24                                   | 71.6         | 96.5            | 34                 | 71.1         | 96              | 18                 | 71.1         | 94.4            | 6                  | 71.8         | 95              |                    |              |                 | 82                 | 71.2         | 95.6            |
| 58 to 59.9....                                           | 8                                    | 70.8         | 99.2            | 16                 | 71.5         | 95.2            | 4                  | 70.1         | 97.7            | 9                  | 70.9         | 88              | 3                  | 65.7         | 99.3            | 40                 | 70.5         | 94.9            |
| 56 to 57.9....                                           | 3                                    | 67.4         | 99              |                    |              |                 | 4                  | 68.7         | 95              | 2                  | 68.7         | 95              | 5                  | 67           | 88.4            | 14                 | 67.1         | 93.5            |
| 54 to 55.9....                                           |                                      |              |                 | 6                  | 65.9         | 97              |                    |              |                 | 2                  | 67           | 92              | 4                  | 66.5         | 91              | 12                 | 66.3         | 93.3            |
| Average....                                              | 72                                   | 71.3         | 97.7            | 71                 | 70.9         | 95.9            | 31                 | 70.8         | 95.3            | 19                 | 69.6         | 91.3            | 12                 | 66.3         | 91.8            | 205                | 70.6         | 95.7            |
| Hard red winter:                                         |                                      |              |                 |                    |              |                 |                    |              |                 |                    |              |                 |                    |              |                 |                    |              |                 |
| 64 to 65.9....                                           | 20                                   | 72.8         | 97              | 13                 | 73.2         | 93.5            |                    |              |                 | 1                  | 74.6         | 97              | 1                  | 71.1         | 99              | 35                 | 73.1         | 95.2            |
| 62 to 63.9....                                           | 25                                   | 73.7         | 95              | 24                 | 73.5         | 94.6            | 19                 | 72.5         | 94.7            | 6                  | 72           | 97.5            | 4                  | 72.2         | 97.8            | 78                 | 73.2         | 95.1            |
| 60 to 61.9....                                           | 4                                    | 72.4         | 98              | 8                  | 72.0         | 94.7            | 7                  | 71.3         | 96.6            | 8                  | 70           | 95.8            | 7                  | 70.3         | 94.9            | 34                 | 71.1         | 96              |
| 58 to 59.9....                                           | 1                                    | 73.1         | 94.5            |                    |              |                 |                    |              |                 | 2                  | 67.3         | 96              | 4                  | 69.9         | 94.6            | 7                  | 69.6         | 95              |
| 56 to 57.9....                                           |                                      |              |                 |                    |              |                 | 2                  | 69.3         | 94.5            |                    |              |                 | 1                  | 66.9         | 94              | 3                  | 68.5         | 94.2            |
| 54 to 55.9....                                           |                                      |              |                 |                    |              |                 |                    |              |                 | 1                  | 63.8         | 91              | 1                  | 68.8         | 89              | 2                  | 66.3         | 90              |
| Average....                                              | 50                                   | 73.2         | 96.3            | 45                 | 73.2         | 94.3            | 28                 | 72.2         | 95.2            | 18                 | 70.7         | 96              | 18                 | 69.1         | 95.4            | 159                | 72.3         | 95.3            |
| Soft red winter:                                         |                                      |              |                 |                    |              |                 |                    |              |                 |                    |              |                 |                    |              |                 |                    |              |                 |
| 62 to 63.9....                                           | 17                                   | 70.3         | 95.8            | 14                 | 69.6         | 95.6            | 6                  | 70.6         | 93.4            |                    |              |                 |                    |              |                 | 37                 | 70.1         | 95.4            |
| 60 to 61.9....                                           | 18                                   | 69.6         | 95.2            | 20                 | 69.8         | 97.6            | 17                 | 69.1         | 95.7            | 9                  | 69.5         | 93.7            | 2                  | 67.1         | 97              | 66                 | 69.5         | 96.7            |
| 58 to 59.9....                                           | 2                                    | 70.4         | 79              | 2                  | 64.2         | 100             | 6                  | 70.2         | 94              | 8                  | 69.3         | 92.8            | 2                  | 67.9         | 91              | 20                 | 69           | 92.3            |
| 56 to 57.9....                                           |                                      |              |                 |                    |              |                 |                    |              |                 |                    |              |                 | 2                  | 60.2         | 84.3            | 2                  | 60.2         | 84.3            |
| 54 to 55.9....                                           |                                      |              |                 |                    |              |                 | 2                  | 65.7         | 95.1            |                    |              |                 | 1                  | 64.4         | 89              | 3                  | 65.3         | 93.1            |
| 52 to 53.9....                                           |                                      |              |                 |                    |              |                 |                    |              |                 |                    |              |                 | 1                  | 65.1         | 75.3            | 1                  | 65.1         | 75.3            |
| Average....                                              | 37                                   | 69.9         | 96.1            | 36                 | 69.4         | 97              | 31                 | 69.2         | 95.3            | 17                 | 69.4         | 93.3            | 8                  | 65           | 88.6            | 129                | 69.3         | 95.3            |

With regard to color, the relation is not so plain. With hard red spring wheat the color seems to vary somewhat with the percentage of sound wheat, but with the other classes there is no great regularity so far as the averages are concerned.

A further analysis of Table III reveals the greater value of test weight and percentage of sound wheat in judging quality when these two factors are considered together. It will be noted that the wheat of highest quality from the standpoint of yield and color is both high in test weight and in percentage of sound wheat and that the wheat of lowest quality is low both in test weight and in percentage of sound wheat. On the other hand, these figures would seem to indicate that a sample which is low in test weight still gives a fairly high yield of good-colored flour provided it is sound. They would also seem to indicate the converse of this, that a sample low in percentage of sound kernels but high in test weight may be of fairly good quality as far as yield of flour and color are concerned, which indicates that the percentage of unsound wheat is not always an absolute measure of the extent of damage.

#### **INSEPARABLE FOREIGN MATERIAL, FLOUR YIELD, AND COLOR OF BREAD.**

In most of the samples milled, even after cleaning and scouring, there remained small percentages of weed seeds, dirt, chaff, and other grains which were ground when the wheat was milled. With the wheat of all classes except the spring wheat, this was such a small amount in the average sample as to be almost negligible. With spring wheat, foreign matter consisting of a variety of weed seeds and other grains, particularly wild oats, was present in amounts sometimes ranging higher than  $1\frac{1}{2}$  per cent. The only noticeable effect of this material on the milling quality as revealed by a study of averages is a reduction of milling yield, as is evidenced in Table IV. This is what would be expected, only small quantities of these substances getting into the flour, as they go largely into the bran and shorts. No effect on the color of flour or bread is apparent from these figures. The effects of specific impurities, such as rye, corn cockle, kinghead, and vetch, have been described by R. C. Miller<sup>1</sup> and investigations along this line are being continued.

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<sup>1</sup> Miller, R. C. Milling and baking tests of wheat containing admixtures of rye, corn cockle, kinghead, and vetch. U. S. Dept. Agr. Bul. 328, 24 p., 10 fig., 2 pl. 1915.

TABLE IV.—General effect of small quantities of inseparable material (other grains, seeds, dirt, and chaff) on yield of flour and color of bread made from hard red spring wheat of the crops of 1911, 1912, and 1913, inclusive.

| Inseparable material. | Number of samples. | Flour yield. | Color of bread. |
|-----------------------|--------------------|--------------|-----------------|
| Range (per cent):     |                    | Per cent.    | Score.          |
| 0.5 or less.....      | 178                | 71.3         | 94.7            |
| 0.6 to 1.....         | 40                 | 70.7         | 97.1            |
| 1.1 to 1.5.....       | 34                 | 69.6         | 96.1            |
| 1.6 or higher.....    | 30                 | 69.4         | 95.3            |

## FLOUR STRENGTH.

## COMPARISONS OF LOAF VOLUME.

The term "strength" as applied to flour has been defined and its significance discussed, as have also the two factors of loaf volume and texture, which in this bulletin are considered as a measure of

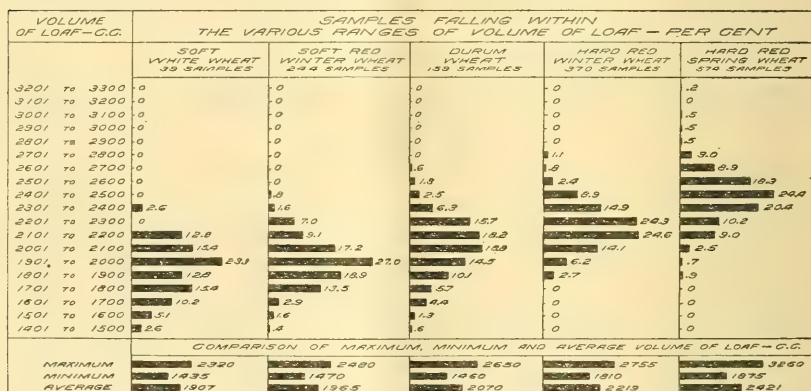


FIG. 12.—Diagram presenting a comparison of the strength of the flour (as indicated by loaf volume) from the five principal classes of wheat, showing variations and averages for each class.

strength. In figure 12 a comparison is made of loaf volume determinations of five classes of wheat, including soft white wheat, with which a comparatively small number of tests were made. This diagram is so arranged as to show the extreme and ordinary ranges for each class, as well as the average, maximum, and minimum loaf volume. From the data here presented it will be seen that the soft white wheats are as a class lowest in strength, soft red winter coming second, with durum, hard red winter, and hard red spring wheats following in order of increasing loaf volume.

The ordinary range in loaf volume for the soft wheats is from 1,700 to 2,200 cubic centimeters, for durum 1,800 to 2,300, for hard red winter 2,000 to 2,500, and for hard red spring wheat 2,100 to 2,700 per 340 grams of flour. The extreme ranges in loaf volume, as indicated by maximum and minimum, are 1,435 to 2,320 cubic centimeters



for the soft white wheat, 1,470 to 2,480 for the soft red winter, 1,460 to 2,650 for the durum, 1,810 to 2,755 for the hard red winter, and 1,875 to 3,260 for the hard red spring wheat. The figures show great variation, which is the result of growing these wheats under a wide range of conditions of soil and climate. In a general way the data gathered from year to year indicate that unfavorable climatic conditions during the later part of the growing season tend to produce the strongest wheats. This is illustrated with the hard red spring wheat of the years 1911 and 1912. In 1911 the latter part of the season was unfavorable and much shrunk wheat, low in flour yield, was the result. Much of the wheat of that year, however, was of exceptional strength. The following year (1912) the opposite was true. Unusually favorable conditions resulted in well-developed wheat high in flour yield, which was, however, of very low average strength for spring wheat.

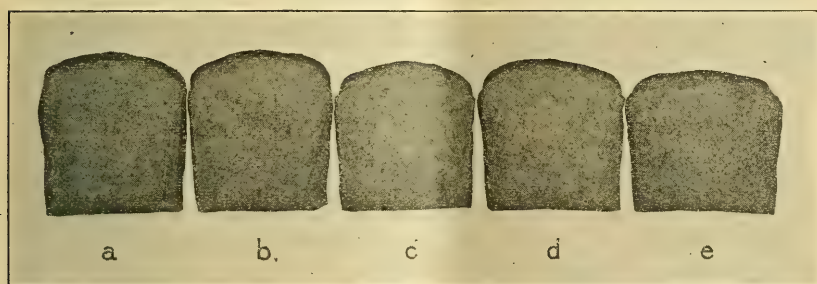


FIG. 13.—Cross sections of loaves of bread made from wheat grown near Shelbina, Mo., showing a considerable range in the quality of low-strength wheat. Loaf *a*, soft red winter wheat, with a volume of 1,935 cubic centimeters and a texture of 94.5; *b*, hard red winter wheat (Turkey), volume 2,075, texture 95; and *c*, *d*, and *e*, soft red winter, with volumes of 1,815, 1,785, and 1,715 and textures of 91.5, 92, and 89, respectively.

One fact clearly brought out by figure 12 is that there is no hard-and-fast line between the various classes, so far as strength is concerned, because of the wide range found in each. When averages are considered, however, differences of considerable magnitude are observed. Soft white and soft red winter are most alike, the average loaf volumes being, respectively, 1,907 and 1,965 cubic centimeters. Durum wheat is a close third, with a volume of 2,070 cubic centimeters, although the flour from this wheat differs in other respects, particularly in color, as was shown in figure 11, and in composition, as will be shown later. Hard red winter and hard red spring wheats have average volumes of 2,219 and 2,421 cubic centimeters, respectively, which shows for these two classes considerable superiority over the others in strength of flour. It shows also that in strength of flour the spring wheat leads the hard winter by a good margin.

Figures 13, 14, 15, and 16, reproduced from a series of photographs, will help to visualize these differences. Figure 13 shows several loaves of bread made from samples of soft red winter wheat and one

of hard winter wheat, all of which were grown in the same locality in the State of Missouri. Loaf *a* is from a sample of soft red winter wheat, and its volume of 1,935 cubic centimeters is about the average for this class; loaf *b* is from a sample of hard red winter wheat of

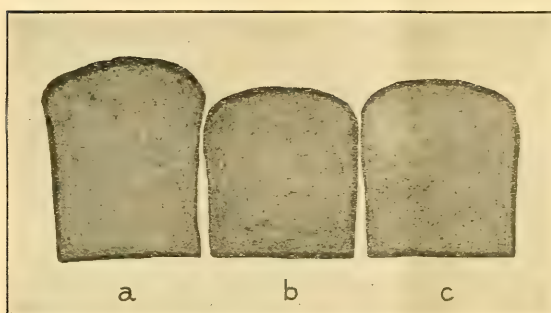


FIG. 14.—Cross sections of loaves of bread made from a high-strength hard red winter wheat and two soft red winter wheat samples of about average strength for this class. Loaf *a*, hard red winter, volume 2,445 cubic centimeters, texture 96; *b*, soft red winter, volume 1,950, texture 88.5; and *c*, soft red winter, volume 1,960, texture 89.

low strength, the volume being recorded as 2,075 cubic centimeters; while loaves *c*, *d*, and *e* are from samples of soft red winter wheat which were somewhat below the average strength, the volumes being 1,815, 1,785, and 1,715 cubic centimeters, respectively.

In figure 14 loaf *a* is from a sample of hard red winter (Turkey)

wheat which is considerably above the average for this class; in fact, its volume of 2,445 is about the average for spring wheat. Loaves *b* and *c* are from soft red winter samples and are very close to the average volume for this class.

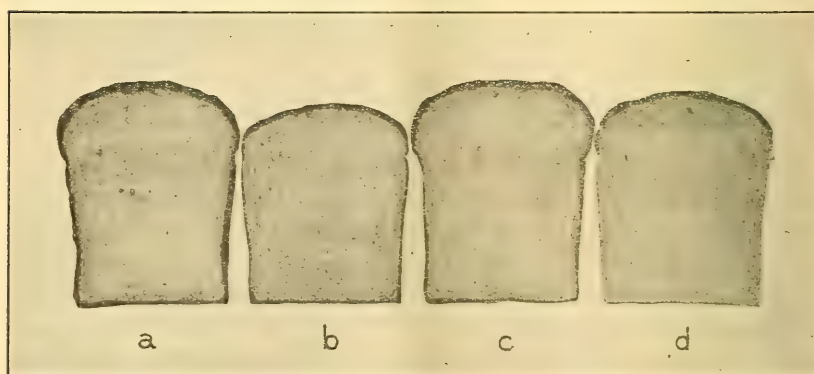


FIG. 15.—Cross sections of loaves of bread made from hard red spring and hard red winter wheat. Loaf *a*, hard red spring, volume 2,615 cubic centimeters, texture 95.5; *b*, hard red winter, volume 2,240, texture 94.5; *c*, hard red spring, volume 2,720, texture 94.5; *d*, hard red winter, volume 2,460, texture 94.

Figure 15 affords a comparison of loaves from hard red winter and hard red spring wheat. Loaves *a* and *c* are from hard red spring wheat and are considerably above the average, their volumes being 2,615 and 2,720 cubic centimeters, respectively. They represent, however, the results commonly attained with the stronger wheats of this class. Loaves *b* and *d* are from hard red winter

samples. The volume of *b* is 2,240 cubic centimeters, which is about the average for this class, and the volume of *d* is 2,460 cubic centimeters, which considerably exceeds the average for this class; in fact, it is a little above the average for hard red spring wheats. It represents, however, the common type of loaf produced from the stronger hard red winter wheats.

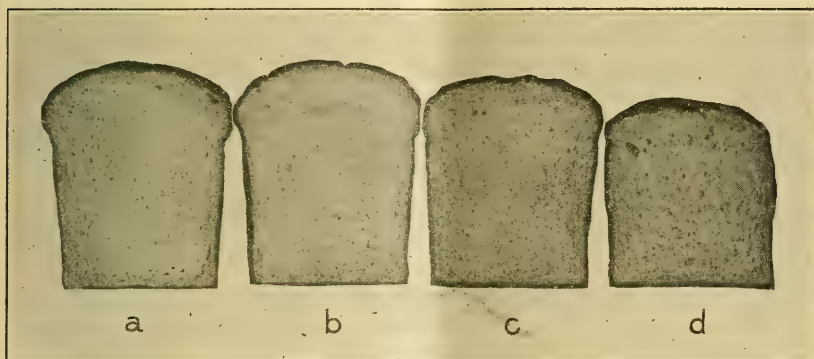


FIG. 16.—Cross sections of loaves of bread, showing a considerable range in the strength of hard red spring wheat and making a comparison of this class with durum wheat. Loaves *a*, *b*, and *c*, from hard red spring wheat and having volumes of 2,520, 2,565, and 2,385 cubic centimeters and textures of 92, 95, and 94.5, respectively; *d*, from durum wheat, having a volume of 1,955 and a texture of 93.5.

Three loaves from hard red spring (*a*, *b*, and *c*) and one from durum (*d*) are shown in figure 16. The volumes are, respectively, 2,520, 2,565, 2,385, and 1,955 cubic centimeters; the first two being above and the last two somewhat below the averages for their respective classes.

#### COMPARISONS OF TEXTURE.

Before going farther with the discussion of strength, the related factor of texture should be considered. Comparisons of texture

| TEXTURE OF LOAF—SCORE         | SAMPLES FALLING WITHIN VARIOUS RANGES OF TEXTURE OF LOAF—PER CENT |                           |                                      |                                      |
|-------------------------------|-------------------------------------------------------------------|---------------------------|--------------------------------------|--------------------------------------|
|                               | SOFT RED WINTER WHEAT<br>197 SAMPLES                              | DURUM WHEAT<br>78 SAMPLES | HARD RED WINTER WHEAT<br>250 SAMPLES | HARD RED SPRING WHEAT<br>364 SAMPLES |
| 99 to 100.0                   | 0                                                                 | 0                         | 0                                    | 5.2                                  |
| 97 to 99.9                    | 7.6                                                               | 6.7                       | 10.4                                 | 17.0                                 |
| 95 to 96.9                    | 11.7                                                              | 9.0                       | 32.0                                 | 35.2                                 |
| 93 to 94.9                    | 26.9                                                              | 25.3                      | 30.0                                 | 20.6                                 |
| 91 to 92.9                    | 19.8                                                              | 16.0                      | 10.0                                 | 11.0                                 |
| 89 to 90.9                    | 15.7                                                              | 18.7                      | 9.6                                  | 5.2                                  |
| 87 to 88.9                    | 12.7                                                              | 9.3                       | 5.2                                  | 1.9                                  |
| 85.9 or lower                 | 5.6                                                               | 16.0                      | 2.9                                  | 1.8                                  |
| AVERAGE TEXTURE OF LOAF—SCORE |                                                                   |                           |                                      |                                      |
|                               | 91.9                                                              | 90.7                      | 93.5                                 | 94.8                                 |

FIG. 17.—Diagram presenting a comparison of the texture of the bread from four classes of wheat, showing their range and the average for each class. Samples from the crops of 1911 to 1913, inclusive.

similar to those of loaf volume are made in figure 17. As the texture scoring system was not used until 1911, fewer samples were available in compiling this diagram, and it was necessary to omit the white wheats. In a general way the variations in texture parallel



those in loaf volume, although the differences are not so marked. The average variation in texture between the several classes is largely an indication of differences arising from the number of cavities in the loaf, which is clearly related to the thickness of the walls of these cavities and consequently to the character of the crumb. When the walls of the cavities are very thin the bread is elastic and yielding to the touch, does not crumble easily when cut into thin slices, but is nevertheless tender and free from toughness. Bread with thick cell walls may be brittle, or very crumbly and harsh to the touch when cold, or rubbery and lacking tenderness. Soft wheats tend toward the former, while the very hard wheats of poor quality tend toward the latter condition.

### RELATION BETWEEN CRUDE PROTEIN IN WHEAT AND THE STRENGTH OF FLOUR.

The strength of wheat flour apparently bears a very intricate relation to its composition. The physical properties of the proteins of

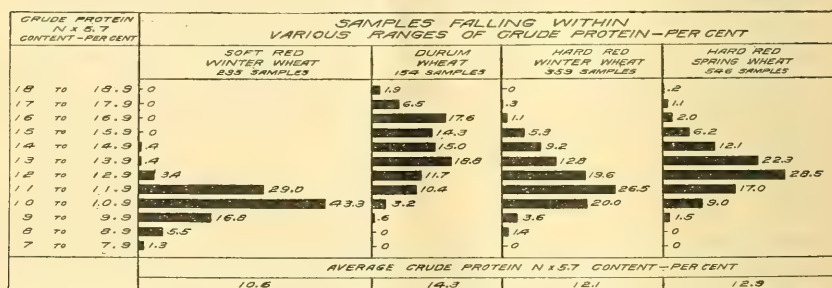


FIG. 18.—Diagram showing the variations in crude protein of four classes of wheat. Samples from the crops of 1908 to 1913, inclusive.

the wheat kernel have long been known to be chiefly responsible for those characters of wheat flour which differentiate it from the flour of other cereals with regard to its ability to retain the gas produced by yeast fermentation.

Figure 18 shows graphically the ranges and averages of the crude protein content of soft red winter, durum, hard red spring, and hard red winter wheats. With soft red winter wheat the extreme range is from between 7 and 8 to between 14 and 15 per cent, nearly 90 per cent of the samples, however, falling between 9 and 12 per cent, the average being 10.6 per cent. This average is 1.5 per cent lower than the next highest, which is hard winter wheat. The crude protein content of durum wheat averages 14.3 per cent and the extreme range is from 9 and 10 to between 18 and 19 per cent, with about 88 per cent of the samples falling between 11 and 17 per cent.

Figure 19 shows the relation between the total crude protein of wheat and the strength of the flour within the three classes of common wheat under discussion.

This shows a general increase in strength with an increase in protein content, the only exception being with hard spring wheat having a crude protein content of over 15 per cent. Between the lower percentages of protein wider variation in volume is noticeable with all classes than between the higher percentages. In fact, many samples having a very high protein content are lower in strength than those having a medium content.

This exception is an illustration of the fact that total crude protein is not always an indication of strength due apparently to differ-

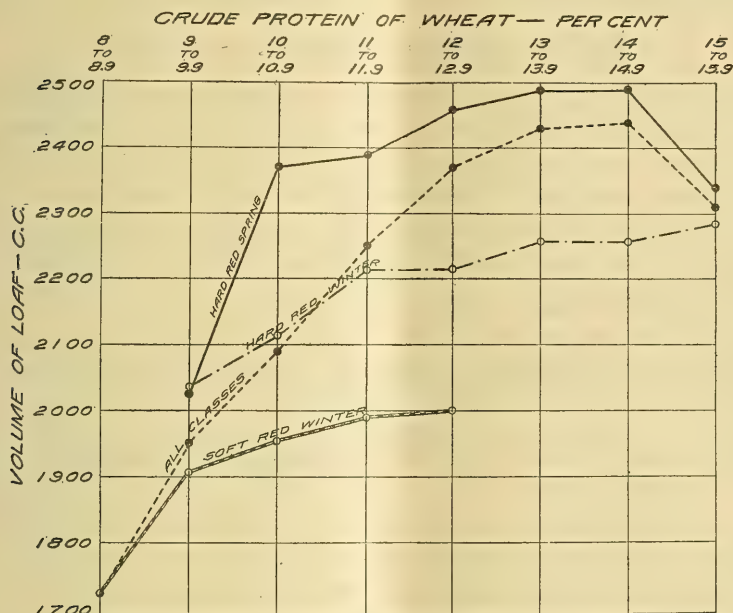


FIG. 19.—Diagram showing the relation between the protein content and the loaf volume of soft and hard red winter and hard red spring wheat. Samples from the crops of 1909 to 1913, inclusive.

ences in the composition or properties of the gluten protein or, as has been shown by the number of investigators, to the presence or absence of associated inorganic substances.<sup>1</sup> In this connection men-

<sup>1</sup>Guthrie, F. B. The absorption of water by the gluten of different wheats. *In Agr. Gaz. N. S. Wales*, v. 7, pt. 9, p. 583-589. 1896.

Fleurent, E. Sur une méthode chimique d'appréciation de la valeur boulangère des farines de blé. *In Compt. Rend. Acad. Sci. [Paris]*, t. 123, no. 19, p. 75-75S. 1896.

Snyder, Harry. The proteids of wheat flour. *In Minn. Agr. Exp. Sta. Bul.* 63, p. 519-533. 1899.

Shutt, F. T. The relationship of composition to bread-making value. *In Canada Cent. Exp. Farms Bul.* 57, pt. 2, p. 37-51. 1907.

Wood, T. B. The Chemistry of strength of wheat flour. *In Jour. Agr. Sci.*, v. 2, pt. 2, p. 139-159, 2 fig.; pt. 3, p. 267-277, pl. 5-6. 1907.

Baker, J. L., and Hulton, H. F. E. Considerations affecting the "strength" of wheat flours. *In Jour. Soc. Chem. Indus.*, v. 27, no. 8, p. 368-376. 1908.

Willard, J. T., and Swanson, C. O. The baking qualities of flour as influenced by certain chemical substances, milling by-products and germination of the wheat. *Kans. Agr. Exp. Sta. Bul.* 190, p. 237-285, illus. 1913.

tion should also be made of durum wheat, which on the average has the highest crude protein of any wheat, but which is of only medium strength.

The wide difference between durum and common wheat in the relation between these factors has been mentioned. Some differences in the relation of crude protein to loaf volume or expansion are also observed with other classes of wheat. For a given percentage of protein the loaf volume is greater for hard red spring wheat than for either hard or soft red winter wheat and is greater for hard winter than for soft winter wheat. This is illustrated in figure 19.

### PROTEIN CONTENT OF WHEAT AND FLOUR.

Since in baking flour is used rather than the wheat itself, it is of interest to note the relation between the protein content of flour and that of the wheat from which it is made. The data in Table V show the general variations to be expected, and it is evident that the protein content of the flour, as a rule, is considerably lower than that of the wheat, though in a small percentage of cases it appears to be slightly higher.

TABLE V.—*Relationship between the crude-protein content of wheat and that of straight flour produced from hard and soft red winter and hard red spring wheat of the crops from 1909 to 1913, inclusive.*

| Crude protein in straight flour. | Proportion of samples falling into various ranges in crude-protein content of wheat (per cent). |             |               |               |               |               |               |               |               |               |
|----------------------------------|-------------------------------------------------------------------------------------------------|-------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
|                                  | 8 to<br>8.9                                                                                     | 9 to<br>9.9 | 10 to<br>10.9 | 11 to<br>11.9 | 12 to<br>12.9 | 13 to<br>13.9 | 14 to<br>14.9 | 15 to<br>15.9 | 16 to<br>16.9 | 17 to<br>17.9 |
| Range (per cent):                |                                                                                                 |             |               |               |               |               |               |               |               |               |
| 17 to 17.9.....                  |                                                                                                 |             |               |               |               |               |               |               |               | 25            |
| 16 to 16.9.....                  |                                                                                                 |             |               |               |               |               |               |               |               | 50            |
| 15 to 15.9.....                  |                                                                                                 |             |               |               |               |               |               |               |               |               |
| 14 to 14.9.....                  |                                                                                                 |             |               |               |               |               |               |               |               |               |
| 13 to 13.9.....                  |                                                                                                 |             |               |               |               | 1.5           | 4.3           | 55.5          | 67            | 25            |
| 12 to 12.9.....                  |                                                                                                 |             | 0.5           | 5.6           | 16.2          | 66.2          | 52.9          | 38.9          |               |               |
| 11 to 11.9.....                  |                                                                                                 |             | 2.5           | 21            | 62.1          | 17.3          | 5.7           |               |               |               |
| 10 to 10.9.....                  |                                                                                                 | 4.2         | 40            | 60.1          | 20.7          | 2.3           | 1.4           |               |               |               |
| 9 to 9.9.....                    |                                                                                                 | 44.7        | 52            | 12.4          | 1             |               |               |               |               |               |
| 8 to 8.9.....                    | 31.7                                                                                            | 46.9        | 5             | .9            |               |               |               |               |               |               |
| 7 to 7.9.....                    | 68.3                                                                                            | 4.2         |               |               |               |               |               |               |               |               |
| Number of samples.....           | 19                                                                                              | 47          | 203           | 224           | 203           | 133           | 70            | 36            | 3             | 4             |

Cases where the protein content of flour is higher than that of the wheat are evidently abnormal and are explained by the differences in the moisture content of the wheat and of the flour. A sample of wheat of unusually high moisture content might appear to have a low percentage of protein, while the flour having a moisture content several per cent lower might appear higher. This seeming inconsistency could be eliminated by calculating constituents to a dry basis, but this hardly seemed desirable, as it makes the interpretation of results more complex from a commercial standpoint.



The average protein content of the wheat and of the straight flour is compared in Table VI. With all three classes the protein in the flour averages about 1 per cent less than in the wheat.

TABLE VI.—*Average crude-protein content of three classes of wheat and of the straight flour made therefrom.*

| Class of wheat.       | Number of samples. | Crude protein (per cent). |                 |
|-----------------------|--------------------|---------------------------|-----------------|
|                       |                    | Wheat.                    | Straight flour. |
| Soft red winter.....  | 215                | 10.6                      | 9.6             |
| Hard red winter.....  | 323                | 12.1                      | 11.2            |
| Hard red spring.....  | 394                | 12.9                      | 11.9            |
| Total or average..... | 932                | 11.9                      | 10.9            |

### WATER ABSORPTION OF FLOUR.

The importance of the water-absorbing power of flour in its relation to bread-making quality has been mentioned. Figure 20 will emphasize what has been said of the connection of water absorption with the weight of the baked loaf. It will be observed that as the absorptive power increases there is a proportional increase in the weight of the loaf, due to the water retained in the bread during baking. That under average conditions the proportion of absorbed water retained remains practically constant is also shown diagrammatically in figure 20.

In figure 21 a comparison is made of the flour from the five classes of wheat under discussion, and it will be observed that the flour from the soft white wheat has the lowest average absorption, while the soft red winter wheat comes second. The hard wheat classes, including the durum, do not show any very great differences, although the hard red winter wheat averages slightly lower than the other two classes. The extreme range in water absorption is narrowest in the soft wheat and widest in the durums. There would seem to be a fairly close connection between the gluten content or crude protein and the absorptive power of flour, as will be seen by comparing figure 21 with figure 18.

### SUMMARY.

(1) Normal, plump, dry, and sound wheat of all classes yields approximately the same percentage of flour. Over 80 per cent of the samples of each of the three classes of the more common wheats, soft and hard red winter and hard red spring, yielded between 67 and 75 per cent of flour.

(2) There is a direct relation between milling yield and the moisture content of wheat, and in a general way the yield varies inversely

with the moisture content. Were it possible to eliminate other factors, such as variation in plumpness of the kernels, it is probable that this relationship would be more apparent.

(3) The weight per 1,000 kernels or average weight of kernels has very little value in judging the potential flour yield.

(4) Although there are frequent exceptions when individual samples are considered, average results show a very striking relation between weight per bushel and flour yield, the latter varying directly

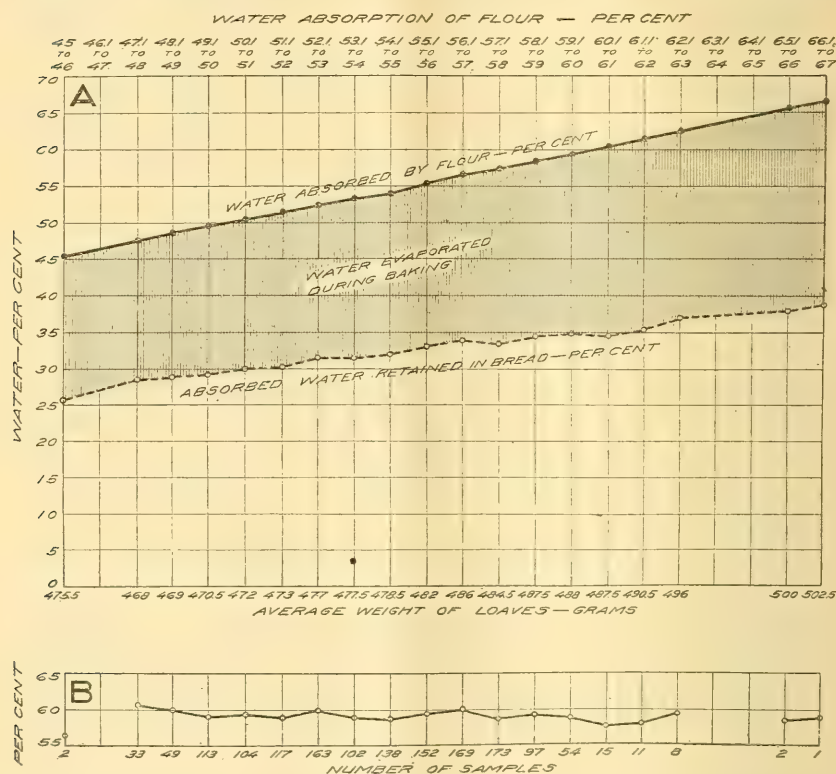


FIG. 20.—Diagram showing the relation between the water absorption of the flour and the total weight and water retention of the baked loaf. A, Comparison of water absorbed by the flour, water retained in the bread, the water evaporated during baking, and the weight of the baked loaves; B, curve showing the proportion of water absorbed by the flour which was retained during baking.

as the former. The ratio between these two figures, however, is not quite the same for the different classes, nor is it the same for all varieties within each class.

(5) In color the bread from the flour of the various classes of common wheat shows about the same ranges and averages. The flour from durum wheat is considerably more creamy and thus averages several points lower than that of any other class.

(6) Bread from all normal durum samples has a tinting or coloration, varying from slightly creamy to bright yellow, while of the hard red winter samples 77.6 per cent show a noticeable creamy tint; of the hard red spring samples, 69.5 per cent; and of the soft red winter samples only 18.9 per cent.

(7) The general results indicate that test weight and soundness, when considered together, are of far more value in appraising quality than when either is considered by itself.

(8) Small amounts of inseparable material are generally accompanied by a decrease in flour yield, as would be expected, in that as a rule a large part of such material usually finds its way into the bran and shorts.

(9) Loaf volume and texture are the two factors which are considered as indicative of strength. While a great range of strength was found within each class of wheat, the averages for each class

| WATER ABSORPTION OF FLOUR—PER CENT         | SAMPLES FALLING WITHIN VARIOUS RANGES OF WATER ABSORPTION OF FLOUR—PER CENT |                                      |                            |                                     |                                      |
|--------------------------------------------|-----------------------------------------------------------------------------|--------------------------------------|----------------------------|-------------------------------------|--------------------------------------|
|                                            | SOFT WHITE WHEAT<br>33 SAMPLES                                              | SOFT RED WINTER WHEAT<br>261 SAMPLES | DURUM WHEAT<br>137 SAMPLES | HARD RED WINTER WHEAT<br>36 SAMPLES | HARD RED SPRING WHEAT<br>262 SAMPLES |
| 67 TO 68.9                                 | 0                                                                           | 0                                    | 1.6                        | 0                                   | 0                                    |
| 65 TO 66.9                                 | 0                                                                           | 0                                    | 1.6                        | 0                                   | 1.5                                  |
| 63 TO 64.9                                 | 0                                                                           | 0                                    | 1.9                        | 0                                   | 7                                    |
| 61 TO 62.9                                 | 0                                                                           | 0                                    | 2.5                        | 2.5                                 | 5.2                                  |
| 59 TO 60.9                                 | 2.6                                                                         | 0                                    | 17.9                       | 2.6                                 | 15.2                                 |
| 57 TO 58.9                                 | 7.7                                                                         | 2.4                                  | 14.6                       | 2.0                                 | 20.9                                 |
| 55 TO 56.9                                 | 7.7                                                                         | 9.2                                  | 14.6                       | 31.5                                | 20.0                                 |
| 53 TO 54.9                                 | 2.6                                                                         | 26.3                                 | 9.9                        | 13.0                                | 9.7                                  |
| 51 TO 52.9                                 | 23.9                                                                        | 29.9                                 | 16.5                       | 10.2                                | 14.9                                 |
| 49 TO 50.9                                 | 30.0                                                                        | 19.2                                 | 10.2                       | 3.9                                 | 9.7                                  |
| 47.3 OR LOWER                              | 15.4                                                                        | 10.6                                 | 5.7                        | 1.4                                 | 3.4                                  |
| AVERAGE WATER ABSORPTION OF FLOUR—PER CENT |                                                                             |                                      |                            |                                     |                                      |
|                                            | 51.7                                                                        | 52.4                                 | 55.7                       | 55.2                                | 55.7                                 |

FIG. 21.—Diagram presenting a comparison of the water absorption of the flour of five classes of American-grown wheat, showing variation, general range, and average for each class. Samples from the crops of 1908 to 1913, inclusive.

show considerable differences between the various classes when considered as a whole. Given in order from weakest to strongest the classes are soft white, soft red winter, durum, hard red winter, and hard red spring wheat.

(10) The average loaf volume in cubic centimeters for each of these classes is soft white wheat, 1,909; soft red winter, 1,965; durum, 2,070; hard red winter, 2,219; and hard red spring, 2,421. In the matter of texture the several classes stand in the same order, except that soft red winter has a slight advantage over durum wheat.

(11) Of the four more important classes of wheat under consideration, durum is the highest in crude-protein content; hard red spring, second; hard red winter, third; and soft red winter, fourth.

(12) High crude-protein content as a rule is accompanied by high strength, but the relation between these two factors varies with the different classes of wheat and extremely high crude-protein content is sometimes accompanied by a decrease in baking strength.

(13) The average water absorption of the flour from durum and from hard red spring wheat is about the same, and that of hard



red winter is only slightly lower. The water absorption of the soft wheats averages from 3 to 4 per cent lower than for the hard wheats. The range of water absorption of each class varies within wide limits.

(14) There is a direct relation between the water absorption of the flour and the bread yield of a unit quantity of the same. As a rule, the higher the absorption the greater the weight of the loaf.

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# UNITED STATES DEPARTMENT OF AGRICULTURE



## BULLETIN No. 558

Contribution from the Office of Markets and Rural  
Organization

CHARLES J. BRAND, Chief



Washington, D. C.

July 28, 1917

### MARKETING GRAIN AT COUNTRY POINTS.

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*Specialists in Grain Marketing.*

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#### INTRODUCTION.

The need for definite knowledge of methods and costs of marketing grain at country points has led the Department of Agriculture, through the Office of Markets and Rural Organization, to undertake a comprehensive study of the subject. The need for such information has found expression chiefly from three sources: (1) The grain trade of the Middle West, both at country points and at central markets, as well as the farmers of this section; (2) producers and merchants located in the cotton belt, in some parts of which a grain surplus has existed for the first time during the last two years, the successful marketing of which is handicapped by inadequate handling facilities; (3) producers and dealers of the Pacific slope, where the process of transition from the present method of handling grain in bags to the more modern and efficient bulk system, used in the Middle West, is demanding serious consideration.

In order to contribute toward the information needed a general survey of the grain-handling methods in vogue in the surplus-

NOTE.—This bulletin should be of interest to producers, shippers, dealers, and consumers of grain and grain products throughout the United States.

producing grain States of the Middle West was undertaken during the year 1915. Producers, officers and members of grain exchanges at terminal points, managers and owners of country elevators, including cooperative, independent, and "line" elevators, together with the officers of their associations, were interviewed at length, and extended studies were made of methods and costs of marketing grain at country points.

Such a vast amount of information has been obtained that only a general summary of existing conditions will be attempted in this bulletin. It is probable, however, that certain features, of necessity discussed more or less briefly at this time, will be made the subject of future publications.

### **FUNCTION OF THE COUNTRY ELEVATOR.**

In the grain belt the local elevator occupies an important position in the life of the rural community. The importance of the several functions of the elevator varies considerably in different sections of the country.

#### **PROVISION OF LOCAL MARKET.**

The primary function of the country elevator is to provide a local market for the surplus grain of the community. It is the practice in many places for the elevator to remain open throughout the year, thus affording the producer, or others having grain for sale, an opportunity to dispose of it on any business day of the entire year. This everyday market is an important, though not always appreciated, privilege which affords the farmer wide opportunity in the marketing of his crop. It enables him to sell his grain at the time when, in his judgment, the price is the most favorable or to market at a time when it interferes least with other farm operations of greater concern than market-value fluctuations.

#### **SEASON FOR MARKETING.**

In newly developed sections of the country where capital is limited and the production and marketing of grain forms a major portion of the farming operation, the grain is usually marketed immediately after harvest. Almost all the grain which leaves these farms, therefore, is received by the elevators during a period of a few months. In fact, in territories where this system of immediate marketing prevails, many managers close the elevators during the remaining eight or nine months of the year, thus automatically prohibiting farmers who do not wish to sell their grain at harvest time from the full privilege of a local market throughout the year.

When such a community is supplied with several elevators, one or two of them sometimes remain open for business, which provides a



local market at all times. Usually, however, elevators remaining open profit to a less degree than those operating during the harvesting and marketing periods only. The latter are not burdened with excess operating expenses, such as salaries, fuel, light, etc., during that portion of the year when comparatively little grain is received, while the houses kept open throughout the season rarely receive enough grain during the postmarketing season to compensate for the cost of operation. Neither do the latter houses distribute the cost of operation on a per-bushel basis, because the price paid for grain during the heavy marketing season is fixed by competitive houses, which establish their figure upon the short-season basis. If the house open throughout the year attempted to lower prices during the heavy marketing season in order to accumulate a surplus fund for the purpose of meeting operating expenses during the remainder of the year, little grain would be received, because the farmer would sell to the highest bidder, which would be the short-season house. If, however, the house open throughout the year is able to purchase a considerably larger volume of grain during the heavy marketing period than its short-season competitors, it may be in a position to pay the same price, and, on account of the increased volume, to make a proportionately greater profit, thus providing for operating expenses for the remainder of the year. Sometimes side lines are carried to offset the difference in operating expense. It would seem that price and other factors being equal, the houses that seek to operate throughout the year should be encouraged.

#### COLLECTION AND STORAGE OF GRAIN.

Unless the country elevator is operated in connection with a mill or some other manufacturing plant, it does not consume the commodities received from the producers, but functions only as a collecting point from which the grain is started to larger marketing centers or to manufacturer and consumer. Such a collecting and shipping point, if operated economically, is undoubtedly a great convenience to a community. In the absence of such a local market the producer is forced to dispose of his surplus grain at distant points, thus entailing inconveniences and marketing hazards. Hence, to serve as a collecting point for the surplus grain of a community, furnishing at the same time the most direct route to a favorable market, is an important function of the country elevator.

The country elevator also serves as a temporary storage place where small lots of grain delivered by the various producers are collected until a volume is accumulated sufficiently large for economical sale and transportation. In communities where a comparatively small quantity of a certain variety of grain is marketed, several weeks

may be required to accumulate a car-lot shipment. In such instances it is necessary for the country elevator to provide facilities for separate storage of this grain, which makes the cost of handling excessive. Often the prospect of a more favorable future market apparently warrants the storing of grain for a considerable period. Frequently country elevators also store grain for farmers who desire to hold their product for a more favorable market.

#### CLEANING AND CONDITIONING GRAIN.

Some country elevators are provided with equipment for cleaning and conditioning grain. While such equipment is expensive, its use frequently improves the quality of the grain and increases its market value. Sometimes grain comes to the elevator in poor condition, often being dirty, dusty, or with high moisture content, and unless the quality is improved by cleaning or drying, the grain can not be disposed of advantageously. Moreover, grain containing impurities, foreign matter, or a high moisture content is quite likely to become hot in transit, which greatly reduces its value and frequently results in serious financial loss. If the elevator is not provided with suitable equipment for this process such grain must be shipped in the condition in which it is received. The farmer should not place all responsibility for cleaning grain on the elevator. It should be remembered that elevator managers do not pay grain prices for the dirt and water found in a farmer's grain. Rather they establish the price by taking into consideration the necessary expense of placing the grain in marketable condition. The farmer who delivers clean, dry, sound grain should receive a premium over the price paid to his more careless competitor. Farmers who deliver grain of inferior quality should be willing to submit to a discount.

The country elevator in some sections cleans the grain received and returns the screenings to the producers. The screenings are sometimes of considerable value for feeding purposes, selling for as much as \$10 to \$25 per ton. In sections of the country where wild oats are commonly found mixed with the small grains, from 2 to 40 per cent of the grain delivered at the elevator may consist of screenings. At several stations in North Dakota the "dockage" for the 1914 season crop of wheat averaged 6 pounds per bushel. In other words, the equivalent of every tenth load of grain delivered at the elevator was screenings, for which the farmer received no return unless the elevator was provided with cleaning equipment. Sometimes a charge is made for cleaning, usually from 1 to 2 cents per bushel, bulk weight.

Cleaning equipment is much more important in some sections of the country than in others. Houses provided with cleaning machin-

ery usually have the advantage over competitors not so equipped, for obviously they are the only ones that can handle a low-grade crop and market it in proper condition. Ordinarily the farmer will fare better if he cleans his grain on the farm before marketing and retains the screenings for feed.

#### HANDLING SIDE LINES.

The sale of coal, salt, cement, and other side lines may not be listed properly as a function of the country elevator, nevertheless many of them seek such patronage. Side lines are handled by the country elevator as a source of additional profit, the exact amount of which depends upon several factors. Generally speaking, the greater the volume of business the less will be the cost per unit for handling; therefore it is necessary to consider the expected volume of business. This will depend upon several things, especially the demand of the consuming trade and the competition from other merchants. The margin demanded by the dealer to cover cost of handling and profit should depend upon whether the commodities are disposed of on a cash or credit basis. A wider margin must be exacted if sold on credit to cover the interest on the increased capital required to finance the business. Moreover, the difficulty experienced in collecting every claim injects a hazard that must be protected. Many country elevators, particularly those of the cooperative associations, have failed to consider the credit losses, and, as a result, the side lines not only fail to yield a profit but frequently suffer an actual loss, which, in turn, is borne by the profit derived from the handling of grain.

Many elevators attempt to do business on too narrow a margin, particularly those which extend credit. Thus, if flour worth \$2 per bag is handled on a margin of 10 cents, a common practice, the failure to collect for a single bag counteracts the profits from 20 bags. The important item frequently overlooked in handling side lines on a credit basis is the interest on outstanding accounts. Thus, if \$25,000 is invested in an elevator and its equipment and its books show an outstanding credit of \$10,000 or \$15,000, interest should be charged against the entire amount.

In some sections farmers frequently sell and deliver their grain to the elevator but do not request payment for some weeks. The elevator operator who immediately sells the grain has the use of the proceeds without interest pending settlement with the farmer.

The interest on outstanding credit is an important item to be considered in determining the cost of operating the elevator and in arriving at the profits derived from the business. Frequently the money employed to carry credit accounts is borrowed from the local bank or from other sources at the regular interest rate. The elevator is fortunately situated, in that many of the credit customers are farm-



ers from whose grain account the outstanding obligations may be deducted.

The collection of claims does not influence the interest item in its relation to the cost of operation. The opinion is generally expressed that side lines increase but slightly the cost of operating an elevator, since the grain business requires constant attention only at certain seasons of the year, and both men and equipment may properly be employed in handling them during slack periods. Nevertheless, many elevator managers feel that, unless the volume of business justifies the employment of a force giving its entire time to their management, side lines detract from the success of the grain business.

In certain sections of the country the grain business is conducted as an adjunct to some other enterprise, a bank, grocery, lumber yard, or general merchandise store furnishing the chief source of revenue. When this arrangement prevails the elevator usually is regarded as a collection agency for the principal enterprise. A merchant handling such a side line usually pays relatively high prices for grain, conducting his business on a narrow margin, with little or no profit, but depending upon the customer to expend his surplus money in the purchase of other articles of merchandise on which a larger profit is expected. The advantage of this arrangement, from the viewpoint of the merchant, is in obtaining the good will of the producer through the practice of paying high prices for grain that additional patronage may be secured for the principal line of endeavor. For the producer this arrangement is satisfactory provided he is able to purchase as judiciously from the merchant-grain-dealer as elsewhere. Independent grain dealers in competition with an elevator run on this basis, however, are seriously handicapped, as they are forced to meet the prices paid for grain by elevators which are operated with little or no direct profit.

#### METHODS OF PURCHASE.

There are several methods open to the farmer when he is ready to dispose of his grain. It may be sold to a local elevator or, if a carload is available, it may be shipped direct to a terminal market, mill, or other consumer. If the grain is marketed locally, it may be sold a load at a time at the prevailing price or arrangements may be made with the elevator operator to sell it at a fixed price, a date being named when delivery must be completed. Sometimes the dealer places the grain in storage until such time as the grower wishes to sell his crop or the farmer may sell it for delivery at some stated time in the future. Regardless of the manner in which a sale is made, the price usually is established in one of four ways: (1) By a flat rate, (2) by grade, (3) by grade subject to dockage, or (4) by grade after cleaning.

## PURCHASES AT A FLAT RATE.

If purchased at a flat rate, the buyer takes all of the grain at a fixed price. To do this some knowledge must be had of the quality of a farmer's grain or a sufficiently large margin of profit must be demanded as protection against loss in event of poor quality. Under this system of equal price it is evident that the producer of high-quality grain usually receives less than it is worth.

## PURCHASES BY GRADE.

When purchased by grade the price is established for grain of a certain quality. In case the grain delivered is of a lower grade, either because the grain itself is inferior or on account of the presence of dirt, a definite amount is deducted from the price. In the past the grades of the small grains have been determined principally by the test weight per measured bushel, but in some instances other factors, such as excessive moisture, must, smut, damaged and sprouted grains, were also considered. Each of these factors has a definite weight in the grades which are being fixed by the Secretary of Agriculture under the United States grain standards act and will probably be considered more carefully in the future.

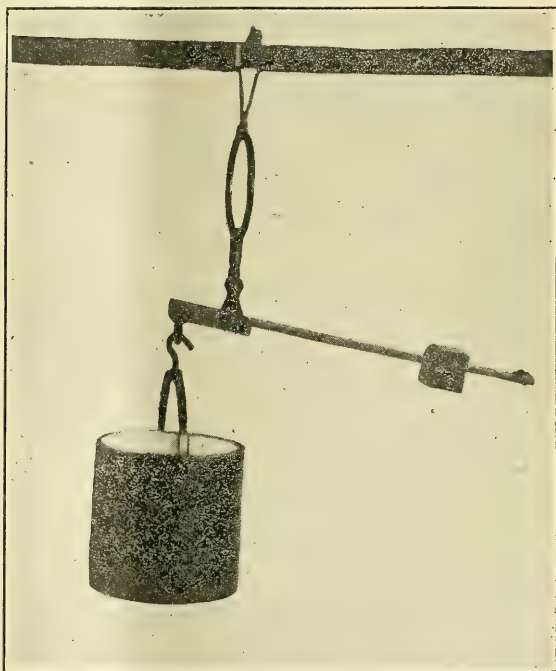


FIG. 1.—Hand tester commonly used at country elevators.

## MAKING TEST WEIGHT.

Farmers generally understand the use of the test weight per bushel, but have no means of knowing all of the other considerations, so for fear of offending the customer the buyer frequently pays more for damaged grain than it is worth, adjusting the loss by a corresponding reduction in the price paid for better grades. The method of mak-

ing a test weight varies widely at different elevators. Usually, however, it is made with a hand scale (see fig. 1), which has a kettle holding one or two quarts, the beam being graduated to read direct in pounds per bushel. The weight can be varied considerably by the manner in which the kettle is filled. Often it is merely dipped into the grain. Again it is partly buried and the grain scooped in over the sides with the hands, or the grain may be poured into the kettle from varying elevations, either a handful at a time or in a constant stream. In removing surplus grain (in order to level the kettle) an instrument is sometimes used that tends to pack it into the kettle. Frequently the kettle is jarred to settle the grain before the surplus is struck off, while in many places the beam of the scale is used for striking off the surplus, and this eventually wears the edges to such an extent that inaccurate weights are obtained. Thus, unless a uniform method of making the test prevails, there is opportunity for considerable variation in the test weight of the same sample.

The department has now adopted, in connection with the enforcement of the United States grain standards Act, a standard method and apparatus for determining the test weight of grain, which is being used generally.<sup>1</sup>

#### VARIATION IN TEST WEIGHT.

During the summer of 1915, 154 samples of wheat, oats, and rye were taken at various elevators in the grain belt, and the elevator operators were requested to supply the test weights as ascertained by them. The samples were then placed in air-tight containers, shipped to the Office of Markets and Rural Organization, and the test weight at once determined with a scale similar to the one used in the standard method adopted by the Department of Agriculture.

The number of samples taken was not sufficient to justify exact conclusions, but the results obtained indicate that there is considerable variation.

Only 10 of the 154 samples showed a higher test weight here than at the country elevator, the maximum difference being 4.5 pounds. Sixteen samples showed no difference, while 128 tested lower here than at the elevator, the greatest variation being 6.5 pounds. The average of the test weights obtained at this office was 1.34 pounds lower than the average of the test at country elevators.

The country dealers frequently allow the test weight that is shown when the poise is moved far enough on the beam to bear it down (as in fig. 1), while the inspectors at terminal markets use the weight shown when the beam balances, or at the nearest half-pound fraction before that point. In this way the farmer frequently secures the

<sup>1</sup> Boerner, E. G. Improved apparatus for determining the test weight of grain with a standard method of making the test. United States Department of Agriculture, Bulletin 472, 1916.



advantage of one-half pound or more in the test. In an effort to offset these losses some elevator operators, where the grade of wheat used as a standard calls for a test weight of 59 pounds, purchase the wheat on the basis of a test weight of 60 pounds.

#### VARIAION IN GRADE.

Deductions are nearly always made when the grain delivered is not equal to the grade contracted, but out of 163 elevators from which data on the subject were obtained only 50 paid a premium to the farmer when the grain delivered was of a higher grade than that commonly purchased. At the remaining 113 elevators the farmer with grain of exceptional quality realized nothing additional for it, any premium which the grain should command being either added to the profits of the buyer or used in equalizing excessive prices paid for inferior grain.

While some attempt at least is made to buy wheat, oats, and other small grains by grade at nearly all points, until recently almost no effort has been made to purchase corn in this manner, the same price being paid for all corn received, regardless of variation in any of the factors contributing to the grade, including color, moisture content, and the percentage of dirt and damaged grains. This method of paying for grain does not offer many inducements to the farmer to handle his grain properly.

Yield and other factors being equal the farmer should grow corn of the color commanding the best price in his market; of a variety showing a low moisture content when properly cared for; should harvest and store his crop in a manner insuring a low percentage of moisture and damaged grain; and should insist, in return, that the dealer pay him for the superior quality of his grain. Samples of corn taken during the fall of 1915 indicated that the dealers were paying the same price for corn ranging anywhere from 19.4 to 25.1 per cent of moisture and containing from a trace to 7 per cent of damaged grain. In one instance a dealer in Ohio paid the regular price for a load containing 23.4 per cent moisture and 6.5 per cent damaged grain, mixing it and other similar loads with other corn of the same color. The carload shipments tested from 21 to 22 per cent moisture at a near-by mill, so it is evident that the shipper was obtaining some corn testing close to 19 per cent. On the day that this load of corn was bought, the elevator manager was paying 50 cents per bushel. He was offered 60 cents on track for corn guaranteed to arrive cool and sweet at New England points, but because of the high percentage of moisture and damaged grain present, it was sold to a near-by mill at 54 cents. It is apparent that if the corn of good quality had been kept separate it might have been sold on the New England bid without assuming any great risk. The near-by mill, which

was equipped with driers, would have purchased the remainder at a very small reduction from the price obtained for the entire lot. If the dealer had kept the better corn separate he could have paid the farmers who marketed good corn considerably more and would not have been compelled to discount the poor corn very heavily. Other dealers were taking yellow, red, white, and white-cap corn all at the same price, although they were selling white and mixed corn at 3 cents under the price of yellow.

#### **PURCHASE BY GRADE SUBJECT TO DOCKAGE.**

By this method the quantity of foreign matter in a sample of the grain is determined by the aid of screens. Settlement is then made on the basis of the weight and grade of clean grain. The dockage system of buying has this advantage over buying by grade without the determination of dockage; a definite deduction is made to cover the weight of the dirt and weed seed in the grain, rather than leaving it to the guess of the buyer. As with the test weight, however, errors are possible in ascertaining the dockage. The method possesses the apparent disadvantage of not allowing the seller anything for screenings, which, in some cases, could be used advantageously for feeding on the farm. Usually, however, the value of the foreign material is taken into consideration in arriving at the price paid for the grain. Grades for wheat established by the department under the United States grain standards Act are made on a dockage basis.<sup>1</sup>

#### **PURCHASE BY GRADE AFTER CLEANING.**

In some sections elevators are equipped with machinery which cleans the grain before it is weighed; the screenings are returned to the farmer, and settlement is made for the weight and grade of the cleaned grain. It is a rather surprising fact that this method is not used more widely than it is at the present time, for while one of the first machines for this purpose were first installed over 20 years ago, the practice is still confined to a relatively small territory. On the whole, it would seem better for farmers either to provide themselves with machinery for cleaning the grain properly on the farms before it is marketed or for the country elevators to adopt more generally the method of cleaning the grain and returning the screenings to the farmers before weighing and grading.

#### **DIRECT SHIPMENT BY THE PRODUCER.**

If the farmer prefers to ship his grain rather than to dispose of it at the local market, the conditions confronting him are similar to those surrounding the country elevator, except that instead of having fairly adequate machinery for loading the grain into cars he usually must shovel it from the wagons into the cars or purchase a portable elevator. The farmer should endeavor to ship at least a

<sup>1</sup> U. S. Department of Agriculture. Office of Markets and Rural Organization. Service and Regulatory Announcements No. 22, 1917.

minimum carload, for he will be compelled to pay freight on at least that amount in any event. This minimum varies in different parts of the country, and the railroad agent should be consulted regarding the precise minimum weight for a carload.

### METHODS OF SALE.

When the country-elevator operator is ready to market his grain it may be sold "on track" or "to arrive," or it may be "consigned." Possibly its disposition may have been effected some months in advance by a sale for future delivery.

#### SALES "ON TRACK" AND "TO ARRIVE."

In nearly all sales "on track" or "to arrive," the price, usually a definite one, is fixed before shipment is made. In the case of an on track sale the buyer pays freight charges, the seller meeting them if the shipment is sold to arrive. The seller, in on track or to arrive sales to interior mills or dealers at points where there is no inspection usually has no other charges to meet, with the possible exception of a bank exchange fee, which is sometimes charged on drafts. In such cases it is customary for the buyer to pay the exchange on on track sales and the seller on sales to arrive. It is also understood, unless the contract of sale specifically provides otherwise, that the shipper guarantees the condition and weights of the grain at destination in a to arrive sale, but in the case of an on track sale he guarantees simply that the weight and grade loaded into a car agrees with the terms of the contract and bill of sale.

In the case of shipment to a terminal market, the consignor, in addition to paying the freight on a to arrive sale, also pays the weighing and inspection charges, and, in some instances, pays interest on draft against the shipment. There are other charges which it is customary for the shipper to meet in certain markets. If the seller in making a sale on track guarantees the weight and grade of the shipment to a market, it is usual for him to pay charges incidental thereto as in a to arrive sale.

In sales to arrive or on track a specified time of shipment such as 3, 5, 10, or 15 days usually is fixed, and shipment must be made within that period. In other instances, terms of to arrive sales call for a specified delivery at destination in the same manner. At times shippers make on track or to arrive sales for delivery some months in the future. Shippers, for example, sell new corn in July and August for shipment in November and December. This practice is not to be generally commended or encouraged, because of the likelihood of future misunderstandings. However, when dealers make future delivery contracts with farmers for their grain it affords them a method of protection against loss on such purchases. In considering either to arrive or on track sales, it must be understood that there are numerous ways in which these contracts may be modified. The



Grain Dealers' National Association has adopted uniform trade rules and a standard form of contract, while many of the terminal markets have similar regulations. To avoid misunderstandings, both buyer and seller should insist on the exchange of written agreements clearly setting forth the terms of sale.

#### CONSIGNMENTS.

When the grain is consigned to a commission merchant at some terminal market it is, in accordance with the shipper's wishes, either sold by the merchant upon arrival or stored in an elevator or held in cars pending further instructions. After final disposition the commission merchant renders an account sale, which sets forth the gross amount received for the car, amount of his commission (usually from one-half to 1 cent per bushel, varying with the market and variety of grain), freight charges, and weighing and inspection fees, together with the interest on any money advanced on the shipment. In some markets there are still other charges, such as switching or elevator fees, in case the grain has to be cleaned, dried, or stored. Any balance due the shipper not covered by amount of draft advanced is then remitted.

#### RELATIVE USE OF METHODS.

From information obtained from various elevators in the surplus-grain States of the Middle West during the year 1915, it appears that approximately 50 per cent of the grain received was sold on track; 29 per cent to arrive; and 21 per cent consigned. In Minnesota and the other grain States of the Northwest nearly all of the shipments from the elevators reporting were consigned, while in States east of the Mississippi over 75 per cent was sold on track, the remainder being about equally divided between sales to arrive and consignments. In Texas and Oklahoma over 50 per cent was sold to arrive and most of the remainder was sold on track, these States consigning very little. The proportion consigned as compared with the amount sold on track or to arrive increased with great regularity from the eastern and southern portion of the grain belt toward the Northwest. Experience and observation show that these proportions will vary somewhat each year in accordance with the condition of the crop, a larger proportion being consigned when the quality is poor than when good. This is due to the fact that when the quality is generally poor a car of good grain frequently is sold at an exceptional premium, while it is impossible to tell what a poor quality is worth by description and a better price can usually be obtained by consigning it to a large market, where all classes of buyers will have an opportunity for examination before bidding for it.

#### PLACE OF SALE.

Usually consignments are made either to commission merchants at terminal points or to small market brokers, the latter ultimately

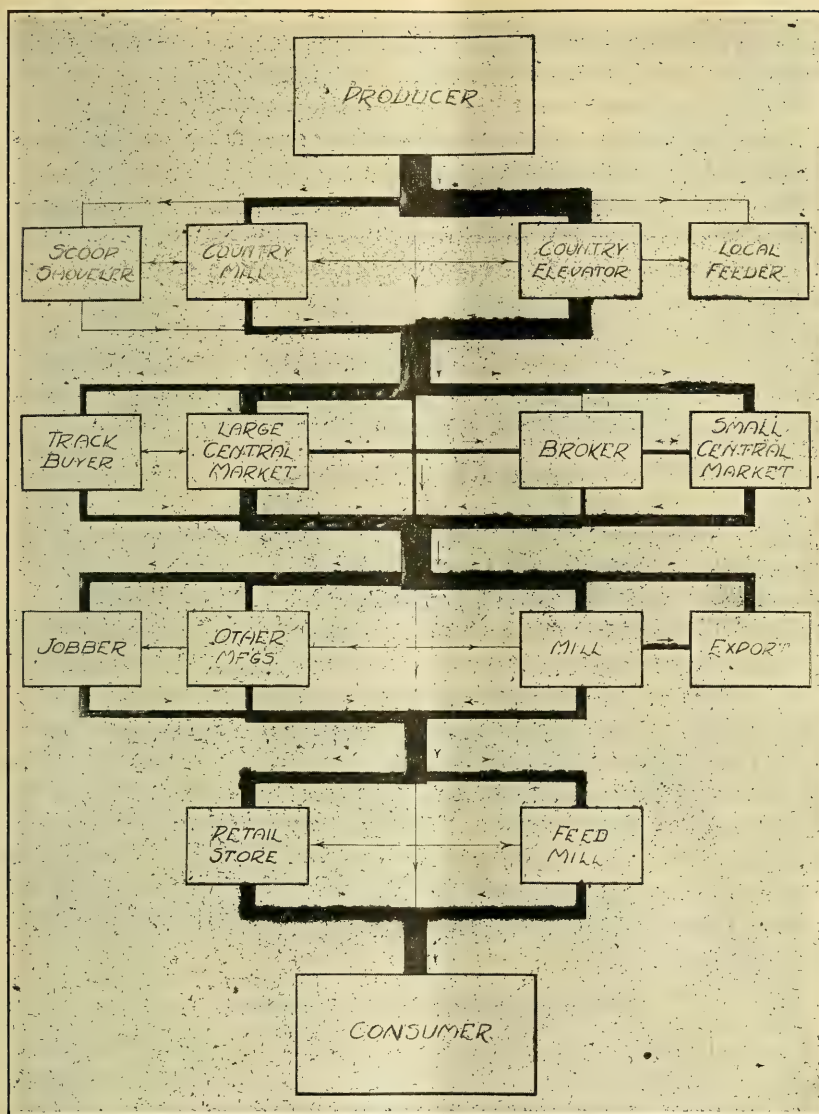


FIG. 2.—Principal channels for distribution of grain and grain products.

The purpose of this diagram is to list the important agencies handling grain and grain products and, in so far as it is possible by means of a diagram, to show their natural relationship to each other and to the producer and consumer. The width of the line leading to and from each agency indicates in a general way the comparative volume of trade passing through this channel, the arrow indicating the direction of the movement. Commercial intercourse between coordinating agencies is indicated by cross lines. In some instances transactions may take place between agencies in the reverse order in which they are listed, thus bringing about what appears from the diagram to be a backward movement. Such transactions, however, are infrequent and do not influence the general direction of the movement to any great extent. The diagram is not intended to show any precise or sharply defined routes traveled by grain in passing through the channels of trade from producer to consumer, nor is it intended to show the relative merit or value of the service contributed by the several agencies to the present system of grain marketing.

disposing of the shipments to local dealers. Sales to arrive or on track may be made direct to buyers at terminal markets, millers, retailers, or consumers, or the services of a broker may be utilized in securing the attention of desirable purchasers (see fig. 2). Grain may also be sold to country track buyers at near-by points, or to carload jobbers in consuming territory.

When a sale is effected through a broker, he may act either as the agent of the buyer or the seller, usually, however, in the latter capacity. A commission usually varying from one-eighth to one-half cent per bushel is paid for his services. In communities where large numbers of buyers congregate it is evident that the broker, by reason of his more intimate knowledge of the conditions in his particular market, is often in position to secure better prices for the grain than his client could possibly hope to attain.

#### TERMINAL-MARKET BUYERS.

The terminal-market buyer either purchases his supply of grain from commission merchants upon the floor of the exchange or direct from outside shippers, subject to the weights and inspection of his market. To the shippers he usually submits to arrive or on track bids by mail or telegraph after the close of each day's market. These offers or bids may be accepted at any time previous to the opening of the market on the following day. The country dealer soon learns that his drafts usually will be met promptly by the terminal market, and also, after a little experience, he knows how his weights will compare with the terminal weights. Purchasers when trading at terminal markets have similar advantages with respect to weights; also, since large quantities of grain usually are held in the elevators at terminals, in most instances dealers are able to make shipments in accordance with the buyer's wishes.

#### DIRECT TRANSACTIONS WITH CONSUMERS.

Numerous mills which are located at terminal markets make their purchases under conditions similar to those affecting other buyers in these markets. When mills are located at secondary points, the shippers soon learn the nature of the weights to be expected from them. The chief objection to the practice of selling to the mills lies in their limited demand. The shipper, before he learns that his grain can not be used, frequently loses the opportunity to make a sale elsewhere. Direct transactions between country shippers and retailers or large consumers usually are confined to those located within a radius of a few hundred miles, such trade being considered highly profitable by those engaged in it, as the shipper and dealer divide between them the profit which otherwise would be made by



the middlemen. Objections to this method of trading are that the small shipper, of necessity, has but a limited amount of grain for sale, and the retailer or consumer is in the market only at infrequent intervals. Often, when the latter wishes to buy, the shipper may have nothing to sell, or vice versa. Then, too, the search for customers frequently entails far greater expense than the amount of profit paid to a middleman for this service.

#### COUNTRY TRACK BUYERS.

Country track buyers usually are located at central points in a shipping territory, where communication by telephone is established easily with numerous shippers. The track buyers purchase grain on track, selling it to terminal markets, millers, jobbers, retailers, or others wherever opportunity presents itself for profitable trading. The advantage of this method lies in the proximity of the buyer to the shipper, a condition materially hastening settlement of accounts and adjustment of disputes. Disadvantages incident to the employment of the country track buyer are (a) frequent inability to obtain official weights and inspection, a condition giving rise to occasional disputes, and (b) lack of storage facilities.

#### JOBBERS AND OTHER MIDDLEMEN.

The jobbers distribute grain to the retailers and consumers in carload lots from central points in consuming territory, usually without rehandling, although some have warehouses or elevators into which carload shipments from producing centers or from terminal markets are unloaded and reshipped in mixed cars. The advantages and disadvantages of the use of the jobber are similar to those cited in connection with the track buyer, with the exception that the latter is in close touch with the shipper, while the former is contiguous to the consumer. Instances where it is practicable and desirable to utilize the services of one or more of these agencies are numerous, but in some cases their use is needlessly multiplied, thus increasing to some extent the cost of handling the grain. Cases are occasionally found where the same car of grain has passed through the hands of several track buyers, terminal market dealers or jobbers, and others before finally reaching the consumer.

#### RELATIVE USE OF METHODS.

Data obtained in 1915 from a number of elevators in the surplus-grain States of the Middle West with regard to the disposition of their grain indicate that 17 per cent of the product from these houses was sold either to terminal markets, track buyers, retailers, or consumers in the same State as that in which the house was located; 25

per cent to interior terminals outside of their own State; 30 per cent. to export terminals; 7 per cent direct to interior buyers, jobbers, retailers, and consumers in Eastern States; 1 per cent to interior buyers in the South; and 20 per cent direct to mills. The small percentage shipped to southern points is probably accounted for by the prevalence of the brokerage system in that section of the country and also by the fact that southern buyers usually purchase grain in bags, a condition impossible for most country elevators to fulfill, owing to lack of proper equipment.

#### PRICE PAID TO THE PRODUCER.

There are many factors which the country buyer must consider in establishing prices to be paid to the producer. If purchases are to be made by grade, prices must be fixed for the popular grade of each variety of grain handled.

#### BIDS RECEIVED BY COUNTRY ELEVATORS.

The dealer receives postal-card bids daily from terminal market dealers, track buyers, and others offering prices for stipulated grades of grain. Telegraph, telephone, and mail bids also are received from these sources at frequent intervals, together with offers from jobbers, brokers, retailers, and consumers. These bids, covering lots of definite size or grade, are so limited in character that they can not be sent out as generally as postal-card quotations. Quotations from the various markets are printed in the newspapers and daily market bulletins are published in the large terminal markets. Many dealers also subscribe to a service furnished by the telegraph companies, whereby they receive the quotations from one or more of the large terminal markets at frequent intervals during the day. This is commonly known as the "C N D" service. News-letters are issued by various commission houses, which contain information regarding the prices at which grain of various grades is selling in the markets, both for immediate and for future delivery, and frequently carry conjectural comments regarding the future trend of prices. From the information obtained from these sources the country buyer must decide what price is obtainable for his grain. The seller must know, in each instance, how his grades and weights compare with those in the market under consideration, as well as the proper amounts to deduct for brokerage, commissions, weighing, inspection, etc., and in the case of bids to arrive or cash prices paid for consigned grain at terminal markets he must be aware of the proper freight charges. The same freight rate does not always apply over all routes between the same points; hence in case the offer is for shipment via a certain route or for delivery on a specified

railroad the shipper must ascertain whether such routing or delivery is possible under the rate quoted.

#### PREMIUMS AND DISCOUNTS.

The establishing and issuing of price quotations from marketing centers is a broad subject, embracing some features that often lead to misunderstanding between the producer and the country-elevator manager and between the manager—especially one with little experience—and terminal market dealers. Price quotations, particularly as they appear in many newspapers, are often misleading and confusing. Some farmers note the top price and expect the local elevator to bid for their grain upon that basis. Frequently the top prices paid in large markets are only for a few cars of extra choice quality of grain, or, as sometimes happens, they represent a premium for a certain kind of grain of which the supply is limited and for which the demand is unusually keen. Thus on July 17, 1915, during the early movement of new wheat, local elevators in a certain country town were offering the farmers \$1.10 per bushel for wheat. Track buyers, representing a large terminal market within shipping distance, were offering the local elevators \$1.14 per bushel. The newspapers, however, appeared with large headlines proclaiming the fact that wheat was selling in this terminal market for \$1.30. Freight rates from the country station to this terminal market were 4.2 cents per bushel. The farmer patrons of the country station concluded that the local elevators were buying their wheat at \$1.10 and reselling it in the central market at a price of \$1.30 per bushel, less freight. When the situation was analyzed it was found that the price of \$1.30 was paid for a single car and that it was an unusual sale, the premium being due to the fact that several millers desired wheat of that particular variety. Owing to the light movement at this time, however, only one car was available, so competitive bidding forced the price to the abnormal level. If at that particular time there had been ten or fifteen cars of the same quality of wheat on the market, undoubtedly the price would have been lower. The country buyers were unable to base their price on premium quotations, because, in all probability, by the time their grain was marketed receipts would have increased materially and the price would have dropped to the normal level for cash grain. The \$1.14 track bids offered to country dealers had taken this fact into consideration, as the bids were made for delivery within two weeks. Commission merchants in the central market published the high premium sale for the purpose of creating a favorable impression of that market among inexperienced country dealers and thereby securing larger consignments.



Frequently premium prices are paid by exporters who need grain to fill out a cargo destined for shipment upon a certain date. Also, as noted in the foregoing illustration, early in the crop year, the first cars of new grain to arrive in the markets are frequently sold at a large premium over prices offered for similar grain to arrive several weeks later. These premium prices are often published without explanation as "cash prices." Dealers forward representative samples of their grain to commission houses or other central market dealers early in the season and are advised that "if your grain were here today" it would be worth a certain price. If the country dealer bases his purchasing price on such information he is quite likely to discover that these early premiums have disappeared by the time his grain arrives, with resultant financial loss to him.

Sometimes a knowledge of discounts is as important as a knowledge of premiums. As a general rule, premiums are paid for grain of superior quality, while discounts are made for grain of "off" grade or inferior quality. When a large amount of high-grade grain is on the market usually little, if any, premium is received. Likewise if but little low-grade grain is on the market it may be disposed of at a slight discount under prevailing prices for good grain. If, however, a large amount of grain is of poor quality the discount is much more severe. Thus grain that under favorable circumstances would sell for 2 or 3 cents discount under the standard grade may be sold at a discount of from 10 to 15 cents when a large amount of grain of the same quality is on the market.

#### UNRELIABILITY OF PUBLISHED PRICE QUOTATIONS.

Local market news, particularly in cities where there is no general market, is sometimes inaccurate. In one instance, in a city of 65,000 inhabitants, under the general head "Grain, hay, and straw (wholesale)," a paper published a mill's price to farmers for wheat and a jobber's quotations to retailers and large consumers for corn, oats, hay, and mill feed. These latter prices were far from accurate, as the following parallel will indicate:

| Commodity.                     | As published. | As actually quoted. |
|--------------------------------|---------------|---------------------|
| Corn.....bushel..              | \$0. 80       | \$0. 55             |
| Oats.....do.....               | . 38          | . 46                |
| No. 1 timothy hay.....ton...   | 10. 00        | 13. 00              |
| No. 2 timothy hay.....do.....  | 10. 00        | 12. 00              |
| Clover mixed hay.....do.....   | 10. 00        | 11. 00              |
| Alfalfa hay.....do.....        | 10. 00        | 15. 00              |
| Wheat bran.....do.....         | 24. 00        | 22. 00              |
| Standard middlings.....do..... | 28. 00        | 25. 00              |
| White middlings.....do.....    | 28. 00        | 29. 00              |
| Mixed feed.....do.....         | 30. 00        | 27. 00              |

When pressed for an explanation of these discrepancies, the market reporter of this paper stated that the wholesaler in question, when asked from time to time, had informed him over the telephone that no changes had occurred. In rebuttal, the wholesaler stated that the paper seldom inquired for price fluctuations and, when notified, failed to insert proper corrections. It is difficult to determine the precise responsibility in instances of this nature, but it undoubtedly is true that the publication of incorrect quotations is a source of annoyance both to the dealer and to the farmer. Dealers in large cities and in country towns should insist that newspapers publish correct quotations, with a specific heading stating the conditions under which they are compiled and the date of compilation.

#### FACTORS INFLUENCING PURCHASE PRICE.

After considering the information obtained from all sources, the buyer may decide to sell his grain for future delivery, although, as previously stated, this practice is not to be commended. Such sales, however, usually have no effect on the price paid to the producer for immediate delivery, for when the dealer is ready to buy grain to fill future contracts, competition usually compels him—when the price is higher—to pay its true worth at that time regardless of the price at which it was originally sold. If the market has declined, the dealer feels that the risk assumed entitles him to any additional profit he may obtain.

When all grain offered is purchased at a flat rate, that is, when one price is paid for all grain of one variety available, the average grade of the grain received must be determined, and this grade is taken into consideration when computing the selling price.

After the dealer has ascertained to his own satisfaction the price he will be able to obtain for the grain, a sufficient amount must be deducted to cover the cost of operation of his plant, together with a fair margin of profit. There are also many other aspects that the dealer must consider in establishing prices. For example, the price paid by his competitors must be taken into account, and he must be aware at all times of the amount of storage space at his disposal and the ability of the railroads to furnish cars when desired.

If, for any reason, the railroads are unable to provide cars as rapidly as needed, the shipper is confronted with the possibility of unfavorable market fluctuations. If shipment can not be effected, the resulting losses must be borne. However, it is usually possible either to sell futures as a hedge against such grain until the time when it can be moved, or to make a cash sale for shipment at a date far enough in advance to enable the dealer to obtain cars. Account must be taken of the condition and quality of the grain, proper con-

sideration being given to the possibility of its deterioration when shipped to distant points. The elevator operator must remember also that at some seasons of the year several days or even weeks may elapse before enough grain of any particular grade will be received to make a carload and an opinion must be formed of the prospective changes in the market during the interval. Many farmers dislike to bother with fractional prices. As terminal prices are quoted in eighths of a cent, and as freight rates are seldom figured in even cents per bushel, the country dealer frequently must decide whether or not he will add the fraction to his profit.

Many farmers and country dealers are influenced to too great an extent by local conditions when attempting to interpret market quotations and anticipate the probable trend of prices. In order to analyze the market and to forecast its bent, it is necessary to take country-wide and even world-wide conditions into consideration. The failure of a wheat crop in one or two counties of a State would hardly influence wheat prices generally to any appreciable extent, but a resident of such a community often fails to consider the relative importance of a local crop to the country's total production.

While all of the factors here enumerated enter into the establishment of the price by the country-elevator operator, in actual practice he usually bases his quotation on one or two of the most important elements, either the bids of a certain dealer or the fluctuations in the cash or future market at a certain terminal with which he is familiar. For example, a dealer finds that during a certain season the to arrive bid of a near-by terminal is the best market obtainable for his grain. Upon receipt of this bid freight charges are deducted, together with an amount deemed sufficient to cover the cost of plant operation and profit.

While most dealers employ this method of price making, good buyers are always observing, consciously or otherwise, all of the various influences here discussed. When an opportunity to "spring the price" presents itself, either by taking advantage of a better price from a consumer, retailer, or some other market, or by proper use of storage, the farmer usually receives the benefit of it, for the dealer is always eager to be in a position to pay better prices than his competitors and thereby handle the major portion of the grain produced in his vicinity.

After a dealer has determined the prices for the standard grades, the prices for grain of other grades offered must be given attention and the necessary amount to deduct from, or add to, the price of standard grades must be ascertained. "Cuts" on "off" grades vary widely and require deep study, and a dealer may suffer heavy losses if a considerable amount of off-grade grain is produced



in his neighborhood. In the hard winter wheat area these cuts usually conform to what is commonly known as the "export scale." This scale is used in adjusting the price of off-grade wheat in New Orleans, Galveston, Kansas City, and other large markets in the Southwest. Usually it is changed each year to meet the condition of the crop but always fixes certain stipulated deductions for each pound that the test weight of the wheat is under the standard and for certain other variations.

In many parts of the country dealers utilize blackboards for posting the prices paid for various grades of grain. This seems to be a wise practice, as the farmer is reasonably certain he is securing the

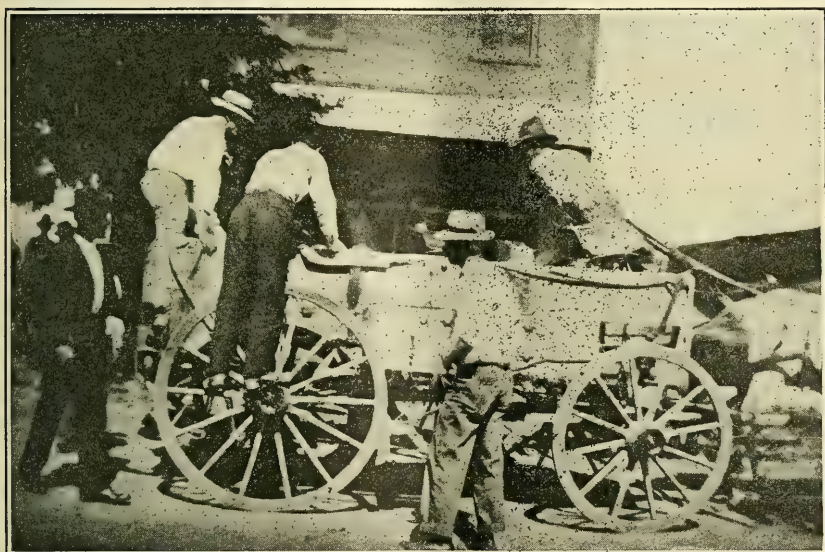


FIG. 3.—Scoop shovelers bidding for a wagonload of wheat.

top price the dealer is paying and the latter avoids the unpleasantness and loss of trade through farmers receiving, or believing that they receive, a lower price for their grain than do their neighbors.

#### TRANSIENT AND PERMANENT "SCOOP SHOVELERS."

In addition to line, independent, and farmers' elevators, there is another group of country grain purchasers known as "scoop shovelers," so called from the fact that they are not provided with the usual equipment for handling grain, but shovel it directly from the farmers' wagons into the cars. These buyers may be subdivided into two classes, transient and permanent. Of transient scoop shovelers there are two kinds: The first consists of retail dealers, liverymen, and others from consuming sections, who visit producing territory occasionally to buy a car or two of grain for their own use; and,

second, those who locate at large shipping points during the rush movement immediately after harvest and handle as much grain as possible while the movement is on, seeking other points when normal conditions are restored. An especially large number of this class of buyers frequent Texas and southern Oklahoma. A large percentage of the itinerant grain purchasers in this territory are cotton buyers who are accustomed to curb bidding. Little cotton is moved during the season of wheat harvesting in July and August, so many of the cotton buyers take a "flyer" in grain. Figure 3 shows four of these buyers bidding for a wagonload of wheat on the public square of a Texas town. When this picture was taken, at the height of the movement, nine scoop shovelers and one elevator company were engaged in buying wheat at this station.

The permanent scoop shovelers usually are farmers, merchants, or liverymen living in the community who seek this method of increasing their respective incomes.

#### METHODS OF BUSINESS.

Owing to the small amount of money invested, the cost of operating a scoop-shovel business is less than that of the regular dealer, who must maintain an expensive plant; but, as the scoop shoveler rarely possesses a thorough understanding of grain-marketing methods, it is seldom that his scope of influence is widely extended. He soon learns that unless a large volume of grain is handled profits necessarily must be meager. On the other hand, the transient buyers not only give regular dealers considerable trouble through loss of business but often cause an appreciable loss to the farmers. In many instances, having little capital (consequently little to lose), they offer prices in excess of market justifications with the hope that before shipments reach a terminal market prices will have advanced sufficiently to afford them a profit. When the market "breaks" against them some one else must bear the loss.

This undesirable state of affairs is created in several different ways. Sometimes an arrangement is effected with a local bank or a prominent merchant to assist in financing shipments by depositing with them whatever capital the buyer may possess. The scoop-shoveler's checks are then honored, the bank or merchant later receiving drafts, with bills of lading attached, when shipments are made, the presumption being that the buyer's small deposit will be sufficient to liquidate any possible losses brought about by market fluctuations. Often, however, the banker discovers this amount to be insufficient, on account of unusual market depression or unsatisfactory quality of the grain, or if for some other reason payment of the draft is refused at destination. At other times the buyer arranges with the farmer to pay for his grain upon receipt of the return remittance, but when the

farmer attempts collection the buyer has disappeared. Often the scoop shoveler may contract to purchase a farmer's grain at a certain figure. If the market declines before delivery is made, the farmer either finds the buyer has gone or that it is impossible for him to take the grain and pay for it. One instance was noted where a scoop shoveler, in contracting for grain from farmers for future delivery, proffered a written contract, which at first glance appeared binding, but further scrutiny disclosed in fine type in one corner these words: "This contract shall not be dated or closed until the above price or better can be paid." This statement meant that unless the price of grain advanced to a profitable point for the buyer before the grain was delivered the contract was worthless.

There are many honest scoop shovelers, including not only consumers or small dealers who come into producing territory occasionally, but also men of limited means who obtain their start in the grain business in this manner. The manager of one of the largest milling companies in the West at the present time made his entry into the grain business with a scoop shovel. For his own protection, however, the farmer should investigate carefully the responsibility of itinerant purchasing agents before selling his grain to them.

While the activities of the scoop shoveler occasionally causes marked losses both to regular dealers and to farmers, as well as to country bankers and merchants, at times his restraining influence upon the country dealer can not be denied. In fact, the manager of a line company operating a large number of country houses recently intimated there was little danger of his company ever seeking excessive margins, for whenever this was attempted scoop shovelers would immediately begin buying grain at each of the stations.

#### CONTRACTING WITH FARMERS FOR FUTURE DELIVERY.

It is the common practice of certain elevator managers to bargain with farmers for the future delivery of grain. In the ordinary course of events such bargains are entered into during the harvesting season, but at times an arrangement providing for the future delivery of grain is agreed upon several months before the grain is actually harvested. In one community it is said that two-thirds of the oat crop is disposed of in this manner soon after the seed is sown.

#### KINDS OF CONTRACTS.

There are two forms of contract in common use. The simplest and most common agreement is one in which the farmer agrees to deliver, on or before a certain date, for a stipulated price, the surplus grain produced upon his farm. This form of contract is sometimes



modified so that the understanding refers only to the grain produced on a certain number of acres, which is known as "contracting by the acre." In another form of agreement the seller undertakes to deliver to the purchaser a definite number of bushels, a proceeding commonly alluded to as "contracting by the bushel." As a rule, contracts for future delivery are mere verbal agreements, although written forms are not unusual. Rarely are any margins deposited by either party to insure actual fulfillment of the contract.

#### HAZARDS OF CONTRACTING FOR FUTURE DELIVERY.

The country grain dealers, as well as the farmers, are seldom in accord regarding the advisability of contracting for future delivery of grain. Many dealers condemn the practice because of the liability of misunderstanding between the dealer and the farmer. From the buyers' standpoint, most unpleasant experiences have resulted from contracting by the acre. It is alleged that some farmers seek to deliver more than the stipulated amount of grain in event of a drop in price, but withhold it, on the other hand, upon a rising market. Then, too, the farmers contend that a material drop in price evokes a disinclination upon the part of the dealers to accept the grain, or finds expression in an attempted discount from the contract price by claiming that the grain delivered does not meet the standard stipulated in the agreement. It would seem that some form of business practice could be devised that would reduce to a minimum the number of such cases.

Many difficulties are encountered in attempting to fulfill the terms of a contract, particularly when an interval has elapsed between the date of the contract and the time of delivery. Often a delayed harvest, accompanied by a prolonged rainy season, renders delivery at contract time an impossibility. When this condition exists it results in much confusion, for the country dealer in many instances has resold the grain by contract, the last purchaser disposing of it perhaps to an exporter desiring to fill a cargo. The failure, for whatever reason, on the part of the farmer to deliver the grain to the country elevator at the specified time interferes seriously with the proper fulfillment of the country grain dealer's previously incurred obligation with other grain merchants. Also, if delivery is not effected upon schedule time the buyer who is dependent upon grain bought for future delivery for the filling of his requirements must purchase the shortage in the open market, often at a marked advance in price. In this case, however, relief is afforded from financial loss by the infliction of a penalty upon the contracting party at fault. The latter, having purchased the grain for future delivery from a country dealer who has been unable to supply it when desired, there-

upon levies a similar penalty upon the elevator. The country dealer experiences more difficulty in shifting his loss upon the farmer, who usually is unwilling to submit to a discount for low-grade grain, or for inability to fulfill a contract. The aggrieved dealer is loath to invoke the aid of civil authorities, fearing the effect of such action upon future business. Of course, the farmer has no recourse, but he should take this matter into consideration when entering into an agreement for future delivery of his grain.

#### ADVANTAGES OF CONTRACTING FOR FUTURE DELIVERY.

The practice of purchasing grain from farmers for future delivery has certain desirable features both for dealer and for producer. The advantages for the dealer are (a) greater certainty of supply and (b) opportunity to sell for future delivery, which enables him to take advantage of any favorable price movement. The farmer, likewise, is at liberty to dispose of his product at any time which, in his judgment, is most propitious to his interests. Nevertheless it would seem that it would be to the advantage of both farmer and dealer if all future-delivery contracts were made in writing, each detail, such as the number of bushels involved, quality of grain, date of delivery, and possible premiums and discounts, clearly and concisely set forth, thereby avoiding the possibility of misunderstanding at any stage of the transaction. It has been suggested also that the welfare of all concerned might be promoted still further if a reasonable margin were posted to insure the good faith of the contracting parties. Inasmuch as this system is followed by members of boards of trade and exchanges in the making of future contracts, it would appear to be a desirable practice and a safeguarding of mutual interests.

#### STORING GRAIN FOR FARMERS.

Frequently the farmer does not market his surplus grain at the time of harvest. Sometimes he may hold it for a more favorable market, while at other times it may not be convenient to deliver it to the local elevator at harvest time, because of the rush of other important farm work.

After small grains have been harvested and after corn has been husked they may be stored on the farm or at the country elevator, or shipped to the central market and there stored in one of the public elevators. Many farms are not provided with suitable granaries, and unless the farmer desires to sell at harvest time he must store his grain either at the local elevator or at the terminal market. Very little grain is shipped from the farms to the central markets for storage.

### STORAGE CHARGES.

Many country elevators provide storage for a limited amount of grain, while other elevator managers do not enter into this phase of the business, preferring to purchase the grain outright at the time of delivery. Many States have regulatory laws regarding the receiving, handling, and storage of grain. In almost all cases the law fixes the maximum charges that may be exacted. Usually the schedule of storage is based on 15-day periods. The schedules of rates may vary from 1 to 2 cents for the first 15 days or parts thereof and from one-quarter to one-half cent for each additional 15 days or part thereof. The variation in the rate prescribed by law in the various States is so great that no exact figures covering the grain-producing area can well be given. Sometimes a maximum charge is defined for continuous storage for a somewhat longer period of time. Thus, one State permits a maximum charge of 4 cents per bushel from the 15th day of November to the 15th day of the following May. Sometimes managers provide free storage for their patrons as long as storage room is available.

### HAZARDS OF ELEVATOR STORAGE.

The matter of storing grain in country elevators for farmers is a subject that has received considerable attention from the grain trade, as well as from the farmers themselves. Several hazards are connected with the storing of grain at local elevators, both for the elevator manager and for the farmer, especially in the absence of laws regulating the business. From the standpoint of the elevator manager the principal objection to the practice is to be found in its interference with the daily buying and shipping business, since when the elevator is full of stored grain its use in receiving and loading out daily receipts is greatly impaired. Frequently managers with their houses filled with stored grain are forced to turn daily deliveries over to a competitor.

The practice of free storage usually has developed from severe competition between houses. One manager may attempt to extend his patronage by offering free storage. His competitor often is obliged to offer the same inducement to hold his trade.

The practice of free storage adds several items to the cost of operating the house. In the first place, the grain must be insured against loss by fire, which is an item of considerable expense. Also the manager of the house in almost all cases must bear the burden occasioned by shrinkage of the grain while in store. If a farmer delivers 1,000 bushels to the elevator for storage he expects to have 1,000 bushels returned to him, or to receive payment for that amount when sold.



The burden of insurance and the loss by shrinkage sometimes lead a manager to ship out the grain received for storage soon after delivery, selling it to the central market. In order to protect himself against price fluctuations he goes into the future market and purchases a hedge for a like amount. When the farmer informs him that he is ready to sell the grain, which the farmer supposes is in storage, the elevator manager closes out his hedge, pays the farmer the market price for the grain, and bears the cost of the hedging sale himself. By shipping out the stored grain, however, the manager not only has relieved himself of the expense of insurance and the loss by shrinkage, but he has also been enabled to use or to loan the farmer's money, thus profiting by the interest earnings.

Shipping out the grain delivered for storage is practiced also when a storage charge is made. In this case the elevator derives a profit from the storage charge in addition to the interest on the money received from the grain.

The hazard of storing grain in the country elevator, from the standpoint of the farmer, depends upon the degree of integrity and the financial standing of the elevator manager. Occasionally the grain dealer announces a business failure with limited resources and the farmers whose grain is supposed to be in store are the chief creditors. While such cases are not general, they have sometimes been so frequent as to result in the enactment of a State law placing the storage business under State supervision and requiring the elevator owner to give bond for the protection of his patrons.

The United States warehouse act, recently enacted, authorizes the Secretary of Agriculture to license warehouses for the storage of grain, flaxseed, cotton, tobacco, and wool for interstate or foreign commerce. This act is permissive only and no warehouse is required to be licensed. The act also authorizes the Secretary to inspect warehouses which are licensed under this law or which apply for license.

#### FARM STORAGE.

From the standpoint of the producer the logical place to store grain is on the farm. Several facts, however, must be considered in determining whether such a procedure is profitable. In the first place, it is necessary to provide suitable granaries and cribs, which will require an original outlay of capital upon which interest and depreciation must be considered. It is necessary also to consider natural shrinkage. The amount of shrinkage that may be expected will depend of course upon the nature of the storage, the condition, and maturity of the grain at the time of harvest, and also the length of time it is held in store. As a general rule the small grains may be expected to shrink from 1 to 3 per cent in weight, while the

shrinkage of corn will vary from 8 to 20 per cent, depending upon the moisture content at the time of harvest. With corn the greatest shrinkage occurs in the months of April and May. The loss by rodents and insects also must be considered, which in some cases, particularly with corn, frequently is relatively high. While the fire hazard is not great in farm storage houses, it is advisable to protect stored grain by insurance, particularly if the storage bins are connected with, or adjacent to, other farm buildings. Other items that must be considered are convenience of marketing, condition of roads at time of delivery, cost of labor, interest on the money value of the grain held in storage, the price at harvest time, and the probable price at some future date. It is necessary also to consider the loss that may be incurred by grain going out of condition while in store. Small grains when damp are likely to become musty or bin-burned. When small grains with high moisture content are put in store it is necessary to "handle" them—that is, the grain must be turned frequently to prevent heating and decomposition. In the elevators this is accomplished by transferring the grain from one bin to another or by drying. Corn, when immature and having a high moisture content, can not be stored safely even in the ear unless the crib is provided with ample ventilation and even then the chances of loss may be great. Most terminal elevators and some country houses are equipped with driers, which reduce the moisture content to a point at which the grain may be stored safely.

#### ESTIMATING PROBABLE FUTURE PRICES.

It is impossible, of course, to anticipate, with any degree of accuracy, the probable market value of grain at some future date, since market values fluctuate in response to conditions over which no one has control. Moreover, the influences are world-wide in their scope, and the results frequently can not be anticipated. The only guide that may be considered is the average values of the several grains during each month of the year for a period extending over several years. As a general rule, prices are lower at harvest time and gradually increase to the period of lighter receipts at central markets and until the probable yield of the forthcoming crop can be estimated with some degree of accuracy. For a 10-year period the price of corn has shown an average increase of 10 cents per bushel from the lowest point (January) to the highest point (August).<sup>1</sup> During the same period the average price of wheat has advanced about 12 cents per bushel from the lowest price (in August) to the highest point (in May), while oats show an average increase of 5 cents per bushel from the

<sup>1</sup> Burleson, W. L., and Allyn, O. M., Prices and shrinkage of farm grains, University of Illinois, Agricultural Experiment Station Bul. No. 183, 1915.

lowest (August) to the highest point (May). In the past the natural shrinkage in corn has been so great as to show little profit from storage, while oats and wheat, if a long-time average is taken into consideration, have been stored at a profit.

It should be remembered, however, that relatively low prices at harvest time are due to the fact that a large amount of grain is placed on the market at this time, thereby establishing an oversupply for immediate needs, overtaking local elevators and transportation facilities, and congesting the central markets. If farmers generally withheld their surplus grain from the market at this time, it is quite likely that values would not decline to a point as low as is reached under present methods. Also if farmers generally held their grain until the month at which values are the greatest under present conditions, it is quite likely that prices would not reach as high a level. Probably ideal conditions would maintain and uniform prices would prevail if the grain were stored on the farm and placed on the market as it is needed for consumption. Under this ideal condition the lowest price would prevail at harvest time, with progressive increase in values until the next crop became available. Theoretically the increase in values would be in proportion to the cost of storage, or the "carrying charge." The obvious objection to this practice is that farmers would not release the grain as needed, but would withhold it from the market merely to cause a scarcity and thus force up the price.

One of the principal reasons why grain is now marketed in such large quantities at harvest is because of the necessity of obtaining cash to pay off previously incurred obligations and for operating expenses. It is likely that farm storage of grain will not be practiced generally until some system of credit, based on farm-stored grain, has been inaugurated. The matter of interest on borrowed money, based on stored grains, will not become an added item of expense because this item must be considered, whether available in cash or in the form of stored grain.

#### HANDLING GRAIN FOR FARMERS.

Occasionally elevator managers ship grain to the central market for the account of the producer. This procedure is not general, but its practice is increasing, particularly in the West Central States. The reason for the practice usually is to be found in the belief on the part of the farmer that the local buyer is exacting too much margin. The producer arrives at this conclusion from a study of price quotations from the central markets and a comparison with the prices offered by the local elevator. Sometimes the farmer is justified in objecting to the price offered by the country elevator. Frequently, however, this conclusion is reached because of a lack of



careful consideration of the factors causing the spread in price and because of unreliable newspaper reports. Frequently all of the facts regarding the market conditions are not available or are not correctly interpreted.

Many elevator managers raise the original price offered the farmer if he objects to it, often at their own financial loss. Other managers refuse to increase their bids, but offer to ship the grain on the farmer's account, usually making a charge of 2 cents per bushel for handling the grain through the elevator. The charge for handling through the elevator may or may not reimburse the elevator manager for the cost of the service. Sometimes the service is rendered free of charge. When the returns for the grain are received from the central market the entire amount, less the handling charge of 2 cents per bushel, is turned over to the farmer. Sometimes such transactions result in profit to the farmer, but quite as often they are disappointing.

The farmer who does not have a carload of grain to market at one time can not take advantage of this practice, because the freight and central market charges on less-than-carload lots would be prohibitive.

#### ADVANTAGE OF GROWING UNIFORM VARIETIES.

Grain is handled most economically through the country elevator when uniform varieties are produced in large amounts by the contributing territory. When this condition exists, the elevator manager is able to handle the grain on narrow margins which eventually result in a higher price level to the producer. In many sections of the country, however, several varieties and colors of the same kind of grain are produced and marketed at the country elevator. This is especially true in the wheat-growing region of Oklahoma and in States where white, yellow, and mixed corn and various colors of oats are produced.

When an elevator must handle two or three varieties of the same grain, more bins and capital are required than when uniformity prevails. Moreover, when different colors of the same sort of grain or, as in some sections, when barley, rye, kafir, and other grains are raised in limited quantities and are received at the elevator in small lots, it is necessary to hold the various grades until a carload is accumulated. Not only is supplementary bin space essential, but more capital is required to finance the business, because the elevator manager is forced to expend cash for grain upon its arrival and he is unable to dispose of it immediately and thus regain his capital for future use. Neither is he able to protect himself against price fluctuations by hedging, since the quantity of grain in store is not sufficient to form the basis for future contracts. The result is that the

elevator manager guards against price fluctuations and obtains an equitable rate of interest on the capital involved by purchasing the grain on a relatively wide margin, which means a correspondingly low price to the producer.

It would seem, therefore, that producers should seek to exert some cooperative effort to standardize the varieties, types, and color of grain produced in a community. Such an endeavor, if consummated, undoubtedly would yield satisfactory financial returns for the effort involved. It is quite likely that the standardization of the grain produced in a community would result in a reputation for uniform quality, which at times commands a premium over general market prices.

### FARM AND ELEVATOR SCALES.

One of the causes of considerable misunderstanding between the elevator manager and the farmer is the use of unreliable scales. Elevator scales should be kept in good repair and tested frequently or checked up by comparison with standard weights. In some States the testing is done by an inspector employed by the State or the railroads, while in other places the work is performed by a man in the employ of the State Grain Dealers' Association. In both cases the inspector is subject to call by dealers, who are assessed a standard fee for services rendered. Some grain dealers, however, do not take advantage of the opportunity to ascertain the reliability of their scales.

### IMPORTANCE OF ACCURATE ELEVATOR WEIGHTS.

Many dealers assume that their scales are correct, although they may not have been examined for several years. The scales should be located properly and when doubt exists regarding the accuracy of an elevator's weights, the scales should be tested every six months or at least once a year, before the heavy crop-moving season. Farmers may well inquire when and by whom the scales were last examined. If more interest were manifested in scale inspection and accurate weights generally, there is little doubt that elevator managers would give the subject more consideration.

### LOSSES DUE TO INACCURATE SCALES.

The efficient manager, however, is always anxious to keep his scales in good repair and capable of giving accurate weights, because a business can not be conducted economically unless he can ascertain the exact amount of grain received and shipped out. Losses from inaccurate scales may fall upon the elevator as well

as the farmer, but it is alleged that some elevator operators employ the short-weight method of overcoming shrinkage losses. This is probably true, especially in the case of elevators owned by corporations or associations, where the directors do not understand that grain can not be handled through the elevator without some shrinkage, and the manager fears action on his bond in the event of discrepancies between in and out weights. Where all scales are accurate, shrinkage in handling grain may be determined by comparing the "in" weights with the "out" weights.

#### AID IN FILING CLAIMS.

It is imperative that the out weights be accurate, in order that positive knowledge of the exact weight of each car of grain may be had. It then becomes comparatively easy to establish a check upon the weights received at the central market and, in case of discrepancy, to afford a substantial basis upon which to file claims for losses incurred. The matter of loss in transit, together with the variation in weights at the country elevator and the central market, is a subject demanding careful study. At almost all terminal markets particular attention is paid to the accuracy of the scales, and when variation between shipping and receiving weights occurs the central market is prone to believe the out-weighing scales at the country point are unreliable. On account of the general reliability of terminal-market scales many buyers prefer to make purchases from the terminal market at a slightly additional cost. Some country dealers not only have their scales inspected frequently, but also supply the purchaser with an affidavit of their reliability. It seems likely that some uniform system of scale inspection and affidavit weight records will be installed eventually.

#### TESTING FARM SCALES.

The farmer should not neglect the testing of the farm scales, if he employs them to confirm elevator weights. Many misunderstandings and erroneous conclusions regarding business ethics of parties to a transaction are based on weights secured from farm or elevator scales the accuracy of which has not been verified for a considerable period of time.

Farmers may test the accuracy of their scales by securing ten or twenty 50-pound test weights. These are weighed first at the center of the scale platform. Additional tests should then be made to check the accuracy of the scale by recording the weight registered when the test weights are placed at each corner of the platform. To determine the accuracy of the scale still further the weight of a loaded wagon may be recorded, after which the test weights should



be placed on the platform and the loaded wagon and the test weights weighed together in order to determine whether the scale records accurately the additional 500 or 1,000 pounds. Pitless scales are likely to get out of adjustment unless they are placed on a very substantial foundation.

### SUPPLY OF ELEVATORS.

The number of elevators required to handle the surplus grain of a community will depend upon the volume of grain offered for sale. The requisite number may depend also upon the method of marketing. If the surplus grain of a community is placed on the market in large quantities during a short period of time following the harvest, more elevators, or elevators of greater capacity, will be required than when the surplus grain is delivered more uniformly throughout the year. Also the number of elevators will depend to some extent upon the ability of the railroad to furnish cars when needed.

### ECONOMIC LOSS FROM OVERBUILDING.

In some sections of the country there are more elevators than the volume of business will justify, some communities being supplied with 8 or 10 houses, when 2 or 3 would be adequate. It is unfortunate that in many places new elevators are still being added to an already overcrowded field. The criterion for determining whether or not additional facilities are needed should be the number of elevators serving a community in proportion to the volume of grain marketed and not the number of houses at any one shipping point. The erection of new houses at small stations between larger shipping points necessarily reduces the contributing territory of them all.

As stated earlier in this bulletin, one of the principal items entering into the economy of operating an elevator is the volume of the business transacted. As a general rule, the cost per bushel for handling decreases, as the volume increases, within certain limits. Therefore, as the number of houses serving a certain locality is augmented, the volume of business transacted by each house diminishes, while the cost per bushel for handling the surplus grain of the community through the local elevator is increased.

If too many elevators serve a community bad practices are likely to result. Difficulties arise regarding free storage, weights, dockage, or grades, and, speculation ensuing, the financial ruin of unsuccessful competitors is almost inevitable. If competition is too keen, short weights are sometimes introduced, or speculation is resorted to in an attempt to regain losses. Cases are cited where grain stored for farmers has been shipped out and sold, to be followed by

bankruptcy; or a fire has destroyed the house. There is a remarkably close correlation between the number of elevators serving a community and the fire ratio. An insurance company reports that in one State, noted for its oversupply of elevators, 42 fires occurred within a year; while in another equally prominent grain State, in which the supply of elevators is better proportioned to the demand, but two houses were lost by fire.

### COST OF OPERATING A COUNTRY ELEVATOR.

Accurate information concerning the cost of operating an elevator is not easy to obtain. Many operators do not keep cost accounts; some make rough estimates, while some endeavor to keep accurate accounts; but in each of several hundred cases investigated by representatives of the Office of Markets and Rural Organization some item of the operating cost had been overlooked.

Figures were obtained from operators who had made an effort to ascertain the cost and from those who were willing to state their opinion. These estimates of cost of operating varied from one-quarter of 1 cent to 5 cents per bushel, the average being  $1\frac{9.8}{100}$  cents for houses handling less than 200,000 bushels in 1914;  $1\frac{2.8}{100}$  cents for houses handling over 200,000 bushels; or a general average of  $1\frac{8.5}{100}$  cents. This variation in cost of handling follows about the same ratio in various sections of the country as the margin of profit, being largest in the East and South, decreasing as the central part of the grain belt is reached, but gradually increasing toward the North and West. Most of these concerns when attempting to figure the cost of operation consider only actual expenses, including office salaries, labor, fuel, power, telephone, telegraph, postage, travel, repairs, supplies, and insurance. Sometimes depreciation, together with interest on the investment in plant and working capital, is included, while a very few consider the loss through shrinkage. None were found, however, who attempted to ascertain the loss through overgrading in making purchases.

From the estimates obtained and from first-hand study it is evident that the items of actual expense are practically fixed for each elevator and vary slightly only as changes in the volume of grain handled necessitate the employment of additional low-priced labor and slight increases in the other items that are not nearly in proportion to the increase in the volume of business. Usually these items do not admit of any considerable reduction, although it is possible at times to reduce the amount of labor hire, as well as the insurance on the stock. Substantial reductions may frequently be made in the rate of insurance, both on plant and stock, by effecting inexpensive changes and providing proper fire-control equipment. If the insurance companies are consulted, advice usually is freely extended

with regard to these matters. Bills for fuel, light, and miscellaneous supplies, which include tools, oil, and waste, together with repairs, may be rendered less burdensome by proper attention.

Depreciation on the plant and interest on the investment also should be considered in figuring the cost of operation. When building a new plant it is wise to consider these items with relation to different methods of construction. The amount of necessary working capital is affected also by the method of doing business. If the grain is shipped and drafts drawn as rapidly as a carload of each grade is accumulated, very little capital is necessary; but if large quantities are held for any length of time, pending a more favorable market, or for any other reason, the amount required is increased greatly. For example, figuring interest at 6 per cent, to hold wheat costing \$1 per bushel for 30 days involves an expense of one-half cent per bushel.

#### LOSS FROM SHRINKAGE.

As stated above, few dealers attempt to ascertain the shrinkage of grain in handling, although, on the basis of the few figures submitted, this item amounts to from four-tenths to six-tenths of a cent per bushel. The amount can be reduced considerably by proper precautions. It is a matter of common knowledge among elevator operators that grain can not be unloaded into an elevator or out, even under the most favorable conditions, without some shrinkage. If scales are incorrect, if elevator boots and spouting leaks, if the grain is improperly cleaned, or is damp when received and dries out subsequently, or if it is shipped in poorly-coopered cars that leak while in transit, this loss is increased. Scales should be examined from time to time, and spouts, elevators, and all other machinery should be inspected frequently.

When grain is to be cleaned, care should be exercised that the cleaning machinery is performing its proper functions, is equipped with proper screens, and that the blast from fans and aspirators is so regulated that the grain will be cleaned sufficiently to reach the desired grade without removing any grain of value. A number of cases were noted during the course of this investigation where, through the use of inadequate machinery, the use of too large or too small mesh screens, or an improperly directed blast or air from fans or aspirators, either the grain had not been cleaned sufficiently or a considerable amount of good grain had been sacrificed in the screenings. In the first instance the grade of the grain had not been improved and no adequate return would be received for the cost of cleaning, while in the second case good grain, unnecessarily removed, was sold with the screenings at a relatively low price, thus materially increasing the cost of cleaning.



When the grain is ready to load, care should be taken to have the cars in proper condition to carry the shipment to destination without leaking. The general condition of the car itself must first be considered. If this is satisfactory, all cracks or holes through which grain might leak must be stopped with boards, paper, or burlap. Careful attention must be given to the manner in which grain doors are inserted, that they may not, under the weight of the grain, shift their position or bulge at the top or bottom or where sections are joined. Detailed consideration has been paid to this subject by railroads, shippers, and receivers in recent years, with resulting improvement, but there is opportunity for further progress in this direction. Traffic managers at several of the principal grain receiving markets of the country state that a large percentage of the cars arriving at the present time are leaking and doubtless many others that show no evidence of leakage when standing on sidings at destination leak under the severe strain of road handling.

#### INCORRECT GRADING.

While nearly all operators of country elevators admitted considerable loss, caused by the difference found to exist between buying and selling grades, which, in some instances, was considered in fixing their margin of profit, not one has been interviewed who possessed definite figures on the loss from this source extending over any considerable length of time. Occasionally figures were obtained covering shipments for a short period which showed the loss to be from one-half to 3 cents per bushel, averaging about 1 cent. One shipper purchased four lots of damaged wheat of the 1915 crop from farmers, three of which tested, respectively, 48 pounds, damp and sprouted; 51½ pounds, damp and sprouted; and 53 pounds, damp and sprouted. These three lots were bought at a discount of 10 cents per bushel, while the fourth lot (which tested 58 pounds and had been exposed to rain on several occasions) was purchased without discount. The four lots were mixed and shipped to a terminal market where the mixture graded No. 4 and was taken on contract at a discount of 10 cents per bushel, resulting in a considerable loss to the country merchant.

At the request of the Department of Agriculture 50 samples of hard winter wheat were taken at an elevator during a period of two and one-half months at the beginning of the 1915 crop movement. This elevator bought wheat on a 59-pound test weight basis, with the deduction of 1 cent for the first pound under that weight and 1 cent for each additional one-half pound. A record was maintained of the test weight of the 50 loads as taken by the elevator and samples were sent to the Office of Markets and Rural Organization. Here the

test weight was determined. The amounts thus obtained varied from those at the elevator from five-tenths to 4 pounds, only one sample showing no variation, with an average loss of 1.23 pounds. Estimating the 50 loads at 60 bushels each, the total deduction, using the scale shown above, on the basis of the test weights as obtained by the elevator, would have been \$59.40, while on the test weights obtained at this office it would have been \$121.80—a loss to the elevator of \$62.40, or 2.08 cents per bushel.

In addition to the loss from this source the elevator made no mention of reductions in grade for other reasons than a low test weight, although three samples were dark wheat, 14 dark and yellow, 16 yellow and dark, and 7 yellow. Two samples testing 57 pounds and grading No. 3 on that basis would probably have been graded "sample" on account of being musty; one sample testing 57 pounds would have graded No. 4 on account of being dirty and containing a large amount of cut grain and smut balls. One sample, testing 60 pounds, would have graded "sample" for the reason that it was smutty; another sample (56 pounds) was an almost pure Turkey wheat and should have commanded a premium. Still another sample was so soft that it is probable that it would have been graded red wheat, instead of hard, the price of the former being considerably lower at that time. It is possible that the elevator sustained no loss on account of these defects, as these were only occasional loads whose identity was lost by mixing with a large volume of other wheat, and, for the same reason, no premium could have been paid on the load of Turkey wheat, but it is probable that each load had its effect on the entire lot. If the poor wheat had been docked properly a more attractive price could have been paid for the better grades. Other instances without number could be cited of overgrading or undergrading, but these two are sufficient to indicate the tremendous loss both to dealers and producers from this cause.

There are several reasons for overgrading by the country elevators. Undoubtedly some of it is caused by faulty judgment and ignorance, but by far the greater part is due to the fear of losing customers. Many dealers admitted overgrading, claiming self-protection as the reason.

#### HAZARDS OF THE COUNTRY ELEVATOR BUSINESS.

The hazards of the country-elevator business include variation in crop yields, unfair competition, the use of inadequately constructed and equipped buildings, variation in grades, necessity of properly interpreting market information, contracting for future delivery, storage, car shortages, failure of sellers and buyers to observe contracts, and financial risks.

### VARIATION IN CROP YIELDS.

In some localities, owing to climatic conditions or to the whims of growers, a large variation in the volume of grain marketed is shown from year to year. Sometimes a community producing enough grain to insure exceptional business one year will yield almost nothing the succeeding 12 months. The quality of the crop at harvest sometimes is so inferior that it is impossible for the dealers to market it with a certain profit. Some sections market practically their entire crop immediately after harvest, the balance of the year being spent in unprofitable leisure. In view of all these circumstances, when seeking a location, a dealer should be certain that there will be a sufficient volume of continuous business. He must weigh the possibility of keeping the house open part of the time or combining with his business some desirable side line.

### INADEQUATE CONSTRUCTION AND EQUIPMENT OF ELEVATORS.

Many of the older country elevators and even some new houses are inefficient and poorly constructed. The loss through the use of improperly constructed cleaning machinery and inaccurate scales has been shown. Another handicap under which many elevators labor is the lack of sufficient wagon dumps, elevators, and bins to keep separate the various grades, which would expedite the handling of the grain. The power equipment should be considered carefully. Where it becomes necessary to have steam for drying, it probably is desirable to operate a steam plant, but otherwise the cost usually can be reduced by the use of an internal-combustion engine. At some places electric power can be had at a minimum cost.

### UNCERTAINTY OF GRADES.

At the present time uniform grades have not been established for all grains, and for those that are not the dealer must be acquainted with the grades of each market which is accessible to him in order to place a certain lot of grain to the best advantage. Sometimes the quality of grain deteriorates in transit. It may become sour, musty, or heated from being confined in a practically air-tight car, it may be delayed in transit, or, after arrival at destination, some time may elapse before it reaches the unloading elevator. Possibly a month after the shipment of the grain the buyer finds it out of condition. Dealers are compelled to suffer the losses arising from this source, although when the delay in transit is excessive it is possible usually to recover from the railroad. Many of the exchanges have deemed it unjust to fix the responsibility for unloading delays arbitrarily upon the dealer, and have adopted regulations requiring buyers to call for reinspection within 24 to 48 hours after the arrival of the grain or to bear any ensuing loss.



**INTERPRETING MARKET INFORMATION AND SELLING FOR FUTURE DELIVERY.**

The dealer receives a vast amount of market information from many sources, and to market his grain advantageously he must be able to interpret these data shrewdly. He must decide whether to sell his grain on track, to arrive, or consign it. If he consigns or holds it in storage and hedges against his holdings by selling an equal quantity for future delivery, he must know where to hedge to best advantage, and assume the risk of variations between the cash and future prices.

Being constantly in contact with the markets he has ever before him the temptation to speculate, either by (1) selling cash grain for future delivery before it is purchased, (2) by holding his purchases without hedging against them, or (3) by dealing directly on the future market. It is only natural that a man who is daily studying market conditions should sometimes feel assured of his ability to forecast the future trend of price fluctuations and to speculate with a certain degree of intelligent judgment, but in most cases he discovers ultimately that his knowledge has its limitation. Conditions arise of whose possibility he was entirely unaware, or has failed to consider, which change the entire trend of prices. When cash grain has been sold he must depend on the farmer's delivery to fill the sale. If the market is rising, farmers naturally withhold their grain in the hope of obtaining better prices. The condition of the roads; stress of farm work, and other circumstances, may militate against deliveries. Should the speculator hold his grain at the elevator some difficulty may be encountered in disposing of it when desired, as mills and other users of cash grain are not inclined to buy freely on a rising market; while if the grain is consigned to a general market there may be a serious decline before its arrival.

**RISKS IN STORING GRAIN.**

The risks incident to storing grain for farmers, contracting with them for future delivery, and advancing money on grain purchased or in store have already been discussed. The dealer must also assume the risk of a car shortage rendering it impossible to ship grain at the desired moment, and possibly compelling him to cease buying because his elevator is filled to capacity. Possibility of deterioration of the grain in storage while awaiting the arrival of cars must be borne in mind. In case the dealer sells grain for future shipments he incurs the risk of buyers failing to fulfill the terms of their contracts. When the market has declined buyers are sometimes financially unable to take the grain, while others seek opportunity to avoid fulfilling their part of the contract by taking advantage of some technical point in its wording.

## FINANCING THE BUSINESS.

Few operators of country elevators have sufficient capital of their own to operate their business and must depend to a considerable extent on outside assistance, which is obtained from several sources, such as local banking institutions, farmers, and commission merchants. In some instances the larger concerns in the Western States obtain the necessary funds from eastern banks or through "paper brokers," in this way reducing the interest rate from 8 or 10 to 5 or 6 per cent. The smaller dealers can not avail themselves of this practice, but in the eastern and southern portion of the grain belt there seems to be little difficulty in securing necessary funds from local bankers, although in some parts of the Southwest the rate of interest ranges from 8 to 12 per cent.

Sometimes local banks are unwilling to furnish the necessary funds, either because they lack sufficient capital or because of the uncertainty of the moral hazard. In these cases the country dealer is usually able to obtain the necessary accommodation from grain commission firms located at central markets. These firms act in the capacity of buffers, securing the money from the banks in the large cities at a rate of 5 or 6 per cent and subloaning it to the country elevators at the same or a slightly higher rate. As compensation for their trouble they receive not only the small difference in the interest rate but also most of the borrower's business. Frequently, one of the conditions under which the loan is made provides that the borrower must consign a certain proportion of the grain he ships (varying from 50 to 90 per cent) to the lender. In a few cases farmer members are leaving returns from their grain with the cooperative companies or loaning them other money; in this way they receive 6 per cent interest on funds on which they would obtain only 3 to 4 per cent at the local banks. But even with all these sources from which to draw needed funds, the country elevator operator at times finds himself unable to secure necessary capital, and either sustains large losses through inability to fill contracts or is compelled to sell his grain at a sacrifice in order to obtain money.

## FURNISHING BAGS TO FARMERS.

In some sections dealers for many years have furnished the farmers with bags for their grain. Upon the approach of harvest the farmer may obtain the bags needed from a near-by dealer, whose hope of remuneration lies in the expectation of purchasing the farmer's grain. Sometimes, however, the farmer disposes of his grain to a rival dealer and the bags are widely scattered over that section. Sometimes, also, the farmer uses as many bags as may be required for the grain held for his own use. Many bags are thus lost and dam-

aged, and the dealer's cost of doing business is increased. Many dealers are opposed to this practice, and in most sections all have abandoned it, but places still remain where certain of the dealers refuse to do so for fear of losing trade.

#### FARMERS' COOPERATIVE ASSOCIATIONS.

The cooperative-elevator movement, which has been attended by both success and failure, has had a rapid development throughout the surplus grain producing territory. Not infrequently the failures have been caused by hasty and ill-advised action in organizing associations. Many farmers enter cooperative elevator associations without giving the matter careful and deliberate consideration. Hasty action is sometimes caused by enthusiasm engendered by professional organizers, who frequently urge the formation of an elevator association without taking into consideration the needs of the individual members and the facilities for grain marketing already available in the community. Erroneous information regarding the cost of operating a plant and the profit from the grain business is sometimes used in order to bring the enthusiasm of the producers to the point of effecting an organization. Associations which have been formed as a result of exaggerated statements regarding the profits that may be expected usually experience considerable difficulty in placing the business upon a successful basis. Not infrequently such efforts are attended by complete failure.

When the organization of a cooperative elevator association is contemplated, careful consideration should be given to the needs of the community for additional marketing facilities. Also definite information should be obtained regarding the volume of grain shipped from the station; usually an average of a 5-year period will furnish more reliable information than the shipments of a single year. If there are established elevator businesses already at the station, a conservative estimate should be made as to what percentage of the total volume of grain shipped from the market will be handled by the cooperative association. Usually the promotors of cooperative associations place the estimate too high. It should be remembered that the established plants will retain some of their former business, and that the volume available to the new association will be reduced accordingly.

After making conservative estimates of the probable number of bushels of grain that will be handled annually, the cost of operating the plant should be estimated. The discussion on page 34 of the cost of handling grain may be of assistance in arriving at a conservative estimate of the cost of operation. With the estimates of the volume of business and the cost of operation as a basis, some deductions may be made regarding the profitableness of the enterprise.



Whenever practicable, associations should purchase existing plants rather than construct new ones, thus avoiding duplication of facilities, with the resulting high cost of operation and reduced profits. In negotiating for the purchase of an old plant the association should secure the services of one or more experienced men to appraise the property.

As a general rule farmers should investigate fully the business circumstances which are to surround the new enterprise before affiliating themselves with the organization. Moreover, it is usually unwise to place too much confidence in what outsiders may say regarding the profits to be derived and the cost of operating a country elevator.

### CONCLUSIONS.<sup>1</sup>

1. Price and other factors being equal, farmers should patronize houses remaining open throughout the entire year.

2. The producer of high-quality grain often receives less than it is worth in order that an equal price may be paid to a grower of grain of inferior quality.

3. The farmer who delivers clean, dry, sound grain should receive a premium over the price paid to his more careless competitor. Farmers who deliver grain of inferior quality should be willing to submit to a discount.

4. Under the present methods of distribution the middleman renders a service to the seller in locating the most favorable outlet for his grain and securing for the buyer grain of the quality desired. However, the number of middlemen may be increased to the point where their efforts become a burden and add needlessly to the cost of marketing.

5. The factors that must be considered in determining the price paid to the producer are so numerous and complicated as to require wide experience and good judgment. Under normal competitive conditions the farmer usually receives full market value for his grain.

6. Market quotations and predictions relating to the probable trend of prices as they appear in some newspapers and market-news letters are often unreliable and should not influence unduly the judgment of elevator managers or farmers.

7. While the "scoop-shoveler" is usually a disturbing element, often causing loss to farmers and others having business relations with him, it is undoubtedly true that he frequently acts as a restraining influence upon the country dealer.

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<sup>1</sup> Much of the text of this bulletin is devoted to a discussion of methods of marketing at country points for the purpose of affording general information which does not lend itself to definite conclusions.

8. Contracts with farmers for future delivery of grain should be entered into only after the interests of both parties concerned are safeguarded by a written contract clearly and concisely setting forth all the details of agreement.

9. In order to determine whether it is profitable to store grain on the farm, it is necessary to consider the interest on the investment, interest on the grain in store, natural shrinkage and loss by rodents, convenience of marketing, condition of roads at time of delivery, price at harvest time, and the probable price at some future date.

10. In the past the natural shrinkage in corn has been so great as to show little profit from storage, while if a long-time average is taken into consideration, oats and wheat have been stored at a profit.

11. It is likely that the standardization of grain produced in a community would not only result in a reputation for uniform quality which at times may command a premium over general market prices, but also reduce the cost of handling grain through the local elevator.

12. Many misunderstandings and oftentimes erroneous conclusions regarding the business ethics of parties to a transaction are based on weights secured from farm or elevator scales, the accuracy of which has not been verified for a considerable period of time.

13. When many elevators serve a community bad practices are usually introduced into the business, which increase the cost of marketing the farmer's grain and depreciate the value of all houses in the town and surrounding territory. Cooperative associations, as well as independent dealers, who desire to enter the business should purchase existing plants if this is practicable rather than build new ones.

14. Losses from shrinkage and overgrading are usually ignored by country elevators. Managers should maintain a system of book-keeping which shows accurately these as well as all other expenses, and a study of the results obtained should enable them to conduct their business in an economic and profitable manner.

15. Grain speculation is always hazardous, especially for those who are so situated that they obtain only a limited amount of information relative to the world's production and markets. The risk is usually greater when speculating with cash grain than in the future markets.

16. The management of a country elevator is a more complicated business undertaking than it would appear to be upon cursory examination. The business is attended by many hazards, all of which should be weighed in advance by those contemplating such activities.

17. When the organization of a cooperative-elevator association is contemplated, careful consideration should be given to the needs

of the community for additional marketing facilities. Usually it is unwise to place too much confidence in the statements made by outsiders regarding the profits to be derived and the cost of operating a country elevator. Farmers should investigate fully the business circumstances which are to surround the new enterprise before affiliating themselves with the proposed cooperative elevator association.



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# UNITED STATES DEPARTMENT OF AGRICULTURE



## BULLETIN No. 559



Contribution from the Office of Markets and Rural Organization  
CHARLES J. BRAND, Chief

Washington, D. C.

July 14, 1917

### ACCOUNTING RECORDS FOR COUNTRY CREAMERIES.

By JOHN R. HUMPHREY, *Investigator in Market Business Practice*, and G. A. NAHSTOLL,  
*Assistant in Market Business Practice.*

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#### ADVANTAGES OF STANDARDIZING ACCOUNTING SYSTEMS.

In modern business, where numerous operating units are conducted along generally similar lines, a distinct tendency toward standardization has been shown. The country creamery offers a problem both of factory and of commercial organization. It is engaged not alone in the preparation and sale of dairy products but in the processing and manufacturing of raw materials into the several finished commodities—butter, cheese, condensed or evaporated milk, casein, and dry and powdered milk. The methods pursued, though varying in many particulars in different sections of the country, are similar in most of the fundamental details. Standardization of accounting methods and business practices, therefore, as in other lines of business, is both desirable and feasible. To this end the adoption of uniform methods of cost and general accounting is a necessary first step.

NOTE.—This bulletin is intended for all farmers' cooperative and other country creameries throughout the United States. It contains copies of forms and a description of their uses for a system of accounts which is being recommended by the Office of Markets and Rural Organization and by the Dairy Division of the United States Department of Agriculture as a uniform system of accounting for country creameries.



A sound and adequate system of accounts is a prerequisite to good management in every organization, and the adoption of a uniform system applicable to the industry as a whole facilitates the interchange of ideas and affords comparisons and collections of data which make for greater efficiency, saner competition, and sounder methods throughout the entire business. An accounting system to be uniformly applicable to both large and small units must be flexible enough to satisfy the needs of all and yet simple enough to appeal to those organizations which do not employ technical bookkeepers. The system presented in this bulletin offers the results of careful study and practical experiment in creameries operating under widely varying conditions. It is designed to meet the increasing need of country creameries which are demanding an efficient and practical method of accounting.

#### TYPES OF CREAMERY ORGANIZATION.

The types of organization found among creameries vary as widely as do those of other marketing associations. Various influences have prevailed to bring about these differences, among which may be cited the preferences of individual outside organizers, the desire of farmers for a free expression of cooperative theory, limitations caused by local competitive or trade conditions, and the legal forms of organization prescribed by State laws. None of these factors, however, have operated to determine any form of organization on a broad scale. Rather, they have brought about variations in the types of individual creameries, even where these have been situated in close proximity to one another. Forms of organization to some extent influence the business relations of creameries to their patrons and thus have a bearing upon the methods of keeping creamery accounts.

Among cooperative creameries, namely, those paying limited stock dividends and distributing the balance of their net earnings in the form of patronage dividends, the most favored form of organization is the stock corporation, with by-law stipulations limiting the ownership of shares by any one member to a prescribed number and distributing the voting power on the basis of membership rather than on ownership of stock. In organizations of this type one vote is allotted to each member. A few creameries are nonincorporated associations, and still others, although incorporated, have no capital stock and in some cases have even no stipulated form of membership.

As a general rule the plan of organization of any association whose operations require the ownership of properties should provide that all capital be subscribed in specific, definite amounts, through the purchase either of shares of capital stock or memberships of stipulated value. This defines clearly the relative financial interest of

each member in the association and indicates the amount of capital subscribed and paid by him to the association. Stock or membership shares may be made redeemable at their face value by the creamery at the time the member severs his connection with the association. Such stock or memberships should then be reissuable to active or new members. This plan will in a measure keep the ownership of the stock or memberships in the hands of resident members.

### OPERATING METHODS.

The methods employed in operating country creameries vary in certain particulars, necessitating also minor variations in accounting forms. Classified according to the principal types, these different methods of operation or forms of organization are as follows: Farmers' cream stations, shipping to centralizers that are owned by either private or cooperative capital; creameries operated both as butter factories and as cream dispensing stations; and creameries operated exclusively as butter and by-product manufactories.

The system of accounts described herein is not intended for simple cream stations, as these will require a much simpler form of accounting, consisting mainly of a cream receipts form, a cash journal, and payment vouchers for the cream purchases. This system, however, is applicable to the other types, and it is not material whether the creamery manufactures all of its raw material or manufactures part and sells the remainder.

Creameries manufacturing by-products, such as cottage cheese, condensed milk, casein, and milk sugar, on a large scale and located in large centers, are not intended to be covered by the system herein described. The specialized needs and complicated requirements of their business should be made the subject of special study before a system of accounts covering their needs is recommended.

In creameries where cream or milk is purchased outright the methods of bookkeeping are not unlike those in other manufacturing concerns. The cost of the raw material is determined in advance of the sale of the manufactured product. This method is reversed in certain cooperative creameries. When it is the intention of the organization to pay back to the producer the entire monthly net income accrued from the sale of the manufactured product the cost of the raw material is figured from the net amount distributable, this being the difference between the gross income and gross operating expense during a given period. The expenses may be computed upon the basis of overrun, or as a fixed charge per hundred pounds of butter, or according to various other permissible methods. The gross income comprises the returns from all products manufactured or sold during the given period. Under this second arrangement

settlements for a given month are figured from the first to the last day of the month and payments made at a convenient time during the month following.

### ACCOUNTING CONDITIONS.

Owing to the lack of specific information in regard to accounting in farmers' creameries, it has been necessary in the past for each secretary, using whatever knowledge of commercial accounting he possessed, to devise a system which in his opinion would best suit the specific requirements of the business, the essential forms being selected from the many which have been placed upon the market by publishing houses catering to the creamery trade. No uniform system was available which could be applied to the needs of practically all country creameries; hence, systems of accounting are practically as numerous as creameries. A few of these are complete double-entry systems, but in most particulars they consist mainly of detached forms, reports, and memoranda designed chiefly to aid the secretary in making up his annual report. The records of the business done by the patrons, including the receipts of milk or cream and of payments made, therefore, are generally satisfactory, as much attention has been paid to this part of the work. But aside from this feature, a large number of accounting systems now in use are inefficient and incomplete; the preparation of an intelligible balance sheet or a statement portraying the results of operation is extremely difficult, if not often impossible, as there is no definite plan for collecting and classifying the items or bringing the totals together.

Local conditions have influenced to a great extent the construction and use of creamery forms. Differences in methods of operation, it was believed, necessitated differences in the manner of keeping records and in the form of records, and no concerted effort was made to bring about uniformity. Such differences were found in the method of deliveries, the frequency of testing, the division of work between the secretary and treasurer, the method of marketing, the frequency of payment, and the form in which the raw material was received. While provision must be made for all these variations, no apparent reason appears why any of them should make necessary any radical change in the accounting system.

### ACCOUNTING REQUISITES.

The cause of a large percentage of business failures may be traced, either directly or indirectly, to the lack of a proper accounting system. Keen competition in present-day business requires that the manager shall command accurate and reliable data regarding his business and the cost and results of operation. Proper accounting includes not



alone the determination of financial standing, but also the determination of the results of operation during any specific period. A system of accounting, to fulfill these requirements, should show at any desired time the assets and liabilities of a business, supplies on hand, expenses incurred, receipts and disbursements of cash, payments made to patrons, profits and losses, and the details of the various transactions affecting operating results.

This information, which is essentially necessary to efficient control and sound management, should be compiled periodically, preferably monthly. It should be recorded in condensed and clarified form on monthly statements, giving full details regarding all items of operation, through the use of properly drawn books of original entry.

An accounting system, however, does not consist merely of books and forms, but, in its broader sense, includes the whole working environment of the office. The best results are obtained with any accounting system when the office is properly equipped with modern appliances, approved and used by the great majority of institutions, namely, proper filing devices, an adding machine, a typewriter, and other facilities for the usual routine of office work.

#### AUDITING.

The importance and desirability of an audit is especially apparent in companies operated on a cooperative basis, since in such companies the patrons are, in a sense, copartners.

The audit should be made by an accountant familiar with creamery accounting and competent to render advisory service to the organization. In some cases creameries employ the services of members to make periodical audits, but as a rule this method is not satisfactory, either to the manager or to the patrons, since audits of this character are at best seldom founded upon any extended knowledge of accounting. Aside from the value of proper accounting itself, probably no other feature in cooperative business enterprise serves to bring about more confidence or create greater business stability than a periodical audit by competent accountants.

#### DESCRIPTION OF THE FORMS.

The forms comprising this system of accounting have been adopted after exhaustive investigation as to their time-saving quality and adaptability to the needs of country creameries.<sup>1</sup> While differences in creamery requirements may suggest changes in some of the auxiliary forms, such as cream and milk receiving sheets, it is not probable that alterations will be necessary in the main features of the system.

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<sup>1</sup> With the close cooperation of the Dairy Division of the Bureau of Animal Industry of this department, this system has been developed in actual operation in creameries selected by that division.

The system is composed of the following forms:<sup>1</sup>

- Form No. 1. Cash Journal.  
 No. 2. Record of Shipments on Consignment.  
 No. 3. Cream Receiving Sheet.  
 No. 3a. Daily Cream Receiving Sheet.  
 No. 3b. Daily Cream Receiving Sheet (Grade).  
 No. 4. Milk Receiving Sheet.  
 No. 5. Patron's Voucher (Duplicate).  
 No. 6. Monthly Operating Statement.  
 No. 7. Patron's Settlement Sheet.  
 No. 8. Buttermaker's Daily Record.  
 No. 9. Butter Balance.  
 No. 10. Patron's Butter Order.  
 No. 11. Local Sales Ticket (Duplicate).  
 No. 12. Consignment Invoice (Duplicate).  
 No. 13. Inventory.

The forms are described in their consecutive order as listed above.

#### CASH JOURNAL.

The cash journal (Form No. 1, p. 24) provides a systematic, chronological reference of the financial transactions occurring during the month and, through the provision of extra columns, reduces the amount of posting to a minimum by assembling items of a similar character into separate totals for the month. The debit columns of this form bear the following headings:

|                      |                      |
|----------------------|----------------------|
| Date.                | General ledger.      |
| Folio.               | Labor.               |
| Cash.                | Repairs.             |
| Bank deposits.       | Freight and drayage. |
| Accounts receivable. |                      |

The credit columns are as follows:

|                           |                                 |
|---------------------------|---------------------------------|
| Folio.                    | Sales, butter shipped.          |
| Check number.             | Butter (local), pounds, amount. |
| Bank withdrawals.         | Buttermilk, pounds, amount.     |
| Accounts receivable.      | Cream, pounds, amount.          |
| General ledger.           | Milk, pounds, amount.           |
| Invoice or ticket number. | Cottage cheese, pounds, amount. |

Two columns in blank are also provided on both the debit and credit sides, which may be used according to the requirements of the individual creamery.

Columns are also provided between the debit and credit sides for items and explanations.

#### RECORD OF SHIPMENTS ON CONSIGNMENT.

In order that a continuous, concise statement may be had of all shipments of manufactured products on consignment to outside markets, the record of shipments on consignment (Form No. 2, p. 25)

<sup>1</sup> In preparing working sets of this system, two binders should be provided, the first containing forms 1 and 2, and the second, forms 6 and 7.

has been devised, setting forth the desired data under the following columns:

|                              |                         |
|------------------------------|-------------------------|
| Date.                        | Returns received, date. |
| Shipped to.                  | Net market Weight.      |
| Shipped via.                 | Price per pound.        |
| Number of packages.          | Amount.                 |
| Shipment number.             | Draft.                  |
| Kind and grade.              | Balance on consignment. |
| Shipping weight, Gross, Net. |                         |

This form serves not only as a memorandum of consignment shipments, but as a basis of computing the inventoriable balance of manufactured products in transit. When a shipment is made, the information available at that time, namely, the date of shipment, to whom shipped, shipped via, the number of packages, the shipment number, the kind and grade, and the shipping weight, should be extended in the appropriate columns. As soon as the returns are received on the shipment the record should then be completed, showing the market weight, the unit price, the amount received for the shipment, and the date of receipt. When drafts are drawn at the time shipments are made, these should be entered immediately in the "Draft" column. It frequently will happen that when the operating statement is being made up certain shipments will be outstanding upon which returns have not been received. When this occurs, the estimated value of the goods should be entered in the "amount" column to ascertain the gross inventoriable value of all outstanding consignment shipments. From the gross value however, must be deducted the amount of all drafts drawn against the various shipments in order to obtain a net outstanding consignment value. This latter is carried over in the "Balance on consignment" column, the total of which for the month is transferred to the inventory sheet under "Butter, net consigned."

#### CREAM RECEIVING SHEET.

Individual preferences of creamery managers for forms for recording the receipt of cream are extremely varied. As the actual design of such forms is not of vital importance, such individual preferences can be exercised freely, so far as these meet the actual requirements of the case. It is not intended that the forms here presented shall be used to the exclusion of all others.

The cream receiving sheet (Form No. 3, p. 25) is so devised that the gross, net, and tare of cans of cream may be shown.

The sections of the form on which are recorded the patron's name and number, either in consecutive order or according to groups by route number, are provided in duplicate, one copy of which is retained in the office and the other used in the receiving department. This latter, with the sheet upon which are recorded the gross, tare,



and net of cream or milk, and the test and pounds of butter fat received, are fastened on a clip board and together form the complete receiving sheet. Each list of names receives a number, which number is assigned also to the corresponding cream receiving sheet. When all receipts of the day have been recorded, the receiving sheet for that date is removed from the clip board and attached to the original list of patrons' names in the office, while a new receiving sheet is placed on the clip board for the following day.

A margin has been provided on the cream receiving sheet, so that they may be pasted together in the order of date to form a complete receiving record for an entire monthly period.

Form No. 3*a*, page 26, is provided for creameries which prefer to keep their receiving record according to date rather than according to list, as suggested under Form No. 3.

A further variation is shown in Form No. 3*b*, page 26, which provides for a daily record of milk receiving sheets according to grade.

#### MILK RECEIVING SHEET.

In creameries which provide separate facilities for receiving milk the records must provide for recording the pounds of milk, the test, and the butter-fat content. Experience has shown that a sheet devised to accommodate the receipts covering an entire monthly period is not satisfactory. The most valid objection is that the sheet is not easily procurable for the use of the bookkeeper until the first of the following month; also, owing to the very nature of his work, the milk handler often so defaces the sheet as to make the figures upon it illegible. The milk receiving sheet (Form No. 4, p. 27) has been devised to overcome these disadvantages.

It provides for the recording of milk receipts for 10-day rather than monthly periods. Its operation is similar to Form No. 3, the cream receiving sheet. Duplicate lists of patrons, with their numbers are provided, and one copy is retained in the office, the other being sent to the receiving department. The milk sheets, however, are usually fastened on the bulletin board attached to the wall in the milk room, in order that they may be accessible to the milk handler.

On the sheet for the third period a column has been provided for extensions, showing the total pounds and the total amount paid for skim milk during the month. This information will be found of valuable assistance in making up the patron's settlement sheet.

#### PATRON'S VOUCHER.

The patron's voucher (Form No. 5, p. 28) has been provided to serve the double purpose of a voucher check and a statement of the patron's account. It is furnished in duplicate, the original going to the patron and the duplicate copy remaining in the office to

serve as the patron's ledger account. On the statement are arranged columns for the following information: Date, cream or milk, test, pounds of butter fat, price, amount, and deductions on account of charges to patrons as follows: Pounds and amount of butter, hauling, and sundries.

The form is designed to accommodate 10 entries of deliveries during the month, but in case patrons make a greater number of deliveries, the statement may be extended to any desired length.

This form has the advantage of presenting to the patron in compact arrangement all the facts regarding his account. It facilitates also the detection of possible errors in calculation. In this connection the patron always should be urged to verify the statement of the creamery with his own records before detaching and cashing the attached check.

#### OPERATING STATEMENT.

The operating statement (Form No. 6, pp. 29-31) is designed for the purpose of facilitating the gathering together of the items of income and expense in order that the amount distributable to patrons may be shown. All items of income, expense, and distribution ordinarily required in country creameries are represented in detail, and columns are provided for the amounts of these items. The different accounts in the books are classified under income, deductions, reserves, and payments to patrons, so that the various steps necessary to the final distribution of the net income of the creamery follow in their proper sequence.

Included with the operating statement is a statement of statistics and formulas for computations. The statistics include data of interest in reference to the conduct of the creamery or of use in computing costs. The computations are designed to explain the method of arriving at the proper distribution of values as recorded on the operating statement.

For the convenience of the creamery a working sheet for trial balances or other general purposes has been provided on the reverse side of the operating statement. All the figures regarding the operation are thus practically consolidated on one sheet.

#### THE PATRON'S SETTLEMENT SHEET.

The patron's settlement sheet (Form No. 7, p. 32) is one of the more important forms in the accounting system. Upon it is based the distribution of income due patrons for raw material. This sheet provides for the recording of the names of patrons, their numbers, pounds of milk or cream, pounds and value of butterfat, pounds and value of skim milk, and gross amount to be distributed for raw material. Deduction columns are included for such items as butter sold to patrons, hauling expense, sundry expense, amounts paid by check, and the amount of current overdrafts.

The "Sundry" column should be used for miscellaneous deductions, such as the sale of supplies on account to patrons, deductions for previous overdrafts, or other items for which special columns have not been provided. For convenience of posting it will be found advantageous to recap the total of the "Sundry" column so that the totals of all similar items may be shown. The remaining columns on the sheet are self-explanatory and are used for the various purposes indicated by their headings.

#### DAILY RECORD.

The butter maker's daily record (Form No. 8, p. 33) is a simple form devised for the purpose of furnishing data regarding the daily run of manufacturing operations in the creamery. It will aid in controlling the overrun and in regulating the uniformity of the product. As a reference sheet, giving information of sources of losses and a comprehensive understanding of the activities in the workroom, it should be of considerable value to both the manager and the butter maker.

#### BUTTER BALANCE.

The butter balance (Form No. 9, p. 33) serves as a perpetual inventory of butter on hand and operates as a check upon the butter-maker's daily record and the record of sales. The butter balance should always check closely with the actual physical inventory at the end of each month.

#### PATRON'S BUTTER ORDER.

The custom of advancing butter to patrons on account without recording the number of pounds is likely to lead to discrepancies which are difficult to locate and correct at the end of the month. In order to avoid this difficulty the patron's butter order (Form No. 10, p. 34) is recommended. No butter should be advanced to patrons unless a signed order bearing the patron's name and number and setting forth the number of pounds for which the order is given has been received from him. These orders should be filed until the end of the month and then be charged to the patron under "Deductions" on the patron's voucher.

#### LOCAL SALES TICKET.

The local sales ticket (Form No. 11, p. 34) provides a simple form for recording both cash and credit sales to local parties. The tickets should be made in duplicate and numbered consecutively, the original being given to the customer and the duplicate being retained in the creamery as a memorandum of sale. All local sales are recorded in the cash journal, the amounts being credited in the "Butter sales—local" column with a corresponding debit entry to cash or to accounts receivable, as the case may be.



## CONSIGNMENT INVOICE.

The consignment invoice (Form No. 12, p. 35) is used for invoicing consignment shipments and should be made in duplicate and numbered consecutively. The information contained therein should be recorded on Form No. 2, the "Record of shipments on consignment".

## INVENTORY REPORT.

In order that the bookkeeper may ascertain the balance on hand of inventorable supplies, it will be necessary to take actual physical inventories at the end of the month. The inventory report (Form No. 13, pp. 36, 37) will be found convenient for this purpose. The various supplies ordinarily used in the operation of the creamery are noted on the form, while blank spaces are provided for other items not enumerated. The report furnishes information as to supplies on hand at the end of the previous month, giving the amount received, on hand, and used during the current month, together with the distribution of the usage as between butter, by-products, and patrons.

## OTHER FORMS.

The forms above described and illustrated in this bulletin are those which are considered practically indispensable in the average creamery. It is apparent, however, that conditions may arise where other forms will be necessary. Among these may be mentioned the following:

1. Duplicate ticket.
2. Hauler's report.
3. Station operator's report.
4. Hauler's or station check sheet.

## DUPLICATE TICKET.

There is considerable variation in the practice of giving receipts for deliveries of the raw product at the creamery. Where such a receipt is required, a ticket form greatly facilitates the work of the receiving room in this respect. The ticket should be made in duplicate, either by means of a carbon sheet or by providing a two-piece tag. In the latter case, the two sections of the tag are numbered correspondingly and each bears the same information respecting the weight of the product received. The lower half of the tag should be torn off and given to the patron as his receipt, the upper part remaining as the record of the creamery. The tickets should be employed merely as memoranda of deliveries.

## HAULER'S REPORTS.

Creameries operating routes on which the cream is weighed and sampled by the hauler should require standard forms for this purpose. These are obtainable from various publishing houses and need not be described here.

**STATION OPERATOR'S REPORT.**

Where creameries operate cream stations from which they receive shipments a station operator's report will be found of great assistance. This report should include the weights and tests of the receipts at skimming or receiving stations. It should be forwarded daily by the station operator to the creamery office, so that information regarding the amount of butter fat received at the station may be available to the butter maker.

**HAULER'S OR STATION CHECK SHEET.**

In the operation of cream-receiving stations and routes, where the weighing and sampling of cream are done by station employees or haulers, a hauler's or station check sheet will be found of value in avoiding losses from dishonesty or carelessness.

**METHOD OF OPERATING THE SYSTEM IN COOPERATIVE CREAMERIES.**

As the Office of Markets and Rural Organization creamery accounting system is intended for use both in cooperative creameries and in those operated under private or corporation management, the method of operating the system will be discussed with relation to the necessities of each type. Since the majority of farmers' creameries are operated cooperatively, the system has been based fundamentally upon cooperative requirements, and the following discussion has reference to its operation in creameries effecting the distribution of their net income on a raw product delivery basis.

**RECEIVING RAW PRODUCTS.**

The receiving sheets for cream should be selected according to the custom of receiving made necessary by local conditions. Form No. 3 is recommended because of the check it affords on the incoming cream. In the use of this form it is necessary to weigh the full cans and the empties in order that the gross, tare, and net may be recorded, and this practice may be recommended as a factor in eliminating the possibility of errors. In case the weight of the cans is marked upon them, either Form 3, 3a, or 3b may be used. When the receipts for the day have been recorded upon the receiving sheet the data should be completed by recording the test and ascertaining the butter-fat content. In the event that composite tests are made the butter-fat content should be computed from the total receipts during the period over which the test extended.

The recording of receipts of milk is similar to that in the case of cream, and the data furnished by these sheets may be obtained in conformity with instructions already given in this bulletin.

## CASH JOURNAL.

The cash journal is designed to facilitate the handling of cash and journal entries. No posting should be made to the ledger other than from entries made on this form. By following this rule the liability of error in posting will be greatly reduced and an explanation of all ledger entries will be obtainable without the extra labor of entering such details in the ledger. The form is so arranged that all debits are entered to the left and all credits to the right of the "Items" column. Because of this arrangement the sum of the totals of entries in columns on the one side should equal that on the other, except that in entering the cash balance at the head of the "Bank deposits" column as the first entry of the month the debit will exceed the credit by that amount.

## USE OF DEBIT COLUMNS.

## CASH.

A "Cash" column is provided for the itemized entry of all cash receipts. At convenient periods the amounts appearing in the column are footed and the total transferred to the "Bank deposits" column. Cash and checks to an equal amount are then deposited in the bank. Footings are not carried forward except when the entries of the day's business extend over to the following page and a subfooting is necessary to secure the full total of the day's receipts. The "Cash" column entries act merely as memoranda of the daily receipts.

## BANK DEPOSITS.

As explained under "Cash" the "Bank deposits" column is used for the purpose of recording daily receipts of cash as deposited in the bank. In order that the total may represent the entire debit to cash at the end of the month, the balance of available cash in the bank at the beginning of the month should constitute the first entry of the month in this column.

## ACCOUNTS RECEIVABLE.

In the "Accounts receivable" column are entered all items representing charges to personal accounts. The individual items are posted to the respective accounts in the ledger, while the total for the month is carried to the debit of the "Accounts receivable control" account in the general ledger.

## GENERAL LEDGER.

All debits to general accounts, not including accounts for which special columns have been provided, should be entered in the "General ledger" column. Such accounts will include capital, income,



expense, and inventory accounts and various other miscellaneous accounts, while the accounts for which special columns are designated include such as labor, repairs, hauling, and drayage. The items in the "General ledger" column are posted individually to their respective accounts, but the totals only of the special columns are carried to the corresponding accounts in the ledger. The "General ledger" column, being in fact a sundry debit column, may be analyzed and the items of similar character recapped, thus affording a reduction in the amount of posting as well as classifying information for use in the monthly operating statement.

#### USE OF CREDIT COLUMNS.

##### BANK WITHDRAWALS.

All checks issued, for whatever purpose, should be entered in the "Bank withdrawals" column, the numbers of the checks being recorded consecutively in the "Check number" column. In the case of payments for the purchase of butter fat or for other raw material where the checks are all drawn at a given time during the month, a single entry in the "Bank withdrawals" column, representing the totals of such checks, is sufficient. The numbers of the first and last checks drawn, as from 101 to 120, will be a sufficient record in the "Check number" column.

##### ACCOUNTS RECEIVABLE AND GENERAL LEDGER COLUMNS.

Items entered in the "Accounts receivable" and "General ledger" columns are of the same nature as those mentioned under the same headings in the discussion of the use of the debit columns. The total of the "Accounts receivable" column should be posted to the credit of the "Accounts receivable control" account in the general ledger.

##### INVOICE OR TICKET NUMBER.

After sales of butter, buttermilk, cream, or other products or supplies are made, the number of the invoice or ticket recording the sale should be entered in the "Invoice or ticket number" column opposite the entry of the amount of the sale. In so far as practicable, all tickets should be entered consecutively in order that sales may be easily located in the cash journal.

##### SALES—BUTTER SHIPPED.

Items in this column represent the checks and cash received for butter consigned to and sold in distant markets and the credits for butter shipments sold on account. Where drafts are made against shipments, such drafts should also be recorded as part of the receipts on account for the butter shipped. The total of this

column will then represent the amount of money received in drafts, checks, and cash for butter sold through outside dealers, plus the value of butter sold on account.

#### OTHER SALES COLUMNS.

The several columns headed "Butter—local," "Buttermilk," "Cream," "Milk," "Cottage cheese," and the two blank columns provided for special use, like the "Sales—butter shipped" column, are used for entry of the sales of the specific product designated. They provide a summary of the income from such sales for each monthly period. The totals of the columns are posted to their respective accounts in the general ledger at the end of the month. The total of the "Butter—local" column, however, is carried, together with the total of the "Sales—butter shipped" column, to the credit of the general "Butter sales" account and not to a separate "Butter—local" account. The sales of butter to patrons should be entered in the "General ledger" column and be posted to the "Butter sales" account.

#### THE LEDGER.

For convenience in operation it is often found advisable to divide the ledger into two parts, so that a distinct division may be made between the general accounts and personal accounts or accounts receivable. Where this method is followed, an account should be carried in the general ledger under the caption "Accounts receivable control." Postings to this account are made once a month and are derived from the totals of the debit and credit accounts receivable columns in the cash journal. It follows then that since the postings to this account are the totals of all debit and credit entries made to individual accounts, the balance of "Accounts receivable" taken individually should equal the balance of the control account. By dividing the ledger into two parts and carrying control accounts in the general ledger, it is also possible to take a trial balance covering the entire operation of the business by reference to the accounts in the general ledger only.

The correctness of the accounts receivable ledger is ascertained by comparison of its balance with that of the control account. The practice of arbitrarily ruling off accounts in the ledger at the end of each month because of the fact that creamery operation usually is divided into monthly periods is not recommended, since it is intended that the ledger shall represent a continuous, accumulated record of the transactions throughout the year. For convenience in making up the operating statement, pencil notations of the monthly balances of accounts may be set down as marginal notations in the ledger accounts, and all entries to the operating statement, except inven-

tories of manufactured goods, should be derived from the monthly balances of accounts, as shown in the ledger. By means of this arrangement the trial balance will afford a complete check upon the monthly operating statement which could not be attained if the ledger were ruled off each month. At the end of the year when the ledger is closed, the net balance of transactions for the complete year should agree with the undistributed balance for the last month of operation, as shown by that month's operating statement.

#### CASH AND PETTY CASH.

In order that a complete trial balance may be taken from the ledger it is advisable to carry a "Cash" account, representing the net balance of available cash in the bank at the end of each month. But one entry a month is necessary to this account, this being the difference between the totals of the "Bank deposits" column and the "Bank withdrawals" column as shown in the cash journal. If the total of the "Bank withdrawals" column should exceed that of the "Bank deposits" column, this account will show a credit balance. Because of the fact that the entries to this account represent balances, it is not necessary to accumulate the items in the ledger from month to month.

For convenience in paying out small sums of money in the form of cash for daily expenses and for making change, a petty cash fund should be established in a sufficient amount to take care of these items. In order to establish this fund, a check should be drawn, crediting cash and debiting petty cash. The fund can then be used as needed. Vouchers for payments of petty cash should be kept on file until the end of the month, when an entry can be made in the cash journal debiting the proper expense accounts for which the payments were made and crediting petty cash. In some creameries it is the custom to use shipping tickets for the transportation of certain products, and in such cases it will be found convenient to purchase a supply of these tickets with the petty cash fund and to treat the tickets as petty cash on hand. This will save a considerable amount of posting of small entries to the "Shipping ticket" account, as a summary of the expenditures of this nature can be made at the end of the month and posted as one item.<sup>1</sup>

#### INVENTORY AND EXPENSE ACCOUNTS.

Accounts covering all inventoriable supplies, such as coal, salt, and tubs, should be carried in the general ledger, together with their corresponding expense accounts. As such goods are purchased the "Inventory" account should be charged. The usage, as shown by the physical inventory, should be credited to the "Inventory" ac-

<sup>1</sup> For further discussion of petty cash see U. S. Department of Agriculture Bulletin 178, Cooperative Organization Business Methods.



count and charged to the corresponding "Expense" account. Butter, milk, cream, and cottage cheese, which may be on hand, should not be carried in accounts in the ledger, as it is the intention to make a complete distribution to patrons for goods of this nature which may be on hand at the end of the month. However, if manufactured goods be on hand at the end of the year when the books are closed, they should be inventoried. These accounts should then be closed and the balance carried forward to the "Operating statement" for the first month of the succeeding year. For example, in the case of butter, this may be accomplished by debiting "Butter inventory" and crediting "Butter sales," thus setting up an asset of butter on hand and showing the amount of income derivable from it. Upon opening the books for the following year a reverse entry should be made, crediting "Butter inventory" and charging "Butter sales," thereby replacing the butter upon the "Operating statement" and debiting the sales for the following year, since credit has been taken for the value of this butter in the sales of the year just closed. Other expense accounts may occur aside from those derived from usage of inventoriable material and these will include such as salaries, office expense, depreciation, bad debts, insurance, repairs, and miscellaneous expense, all of which are derived from entries made in the cash journal.

#### INCOME ACCOUNTS.

Since the income of a creamery is secured from the sale of butter, cream, milk, cottage cheese, and other dairy products, the ledger should carry accounts showing the amount of sales creditable to each of these, and these accounts should be debited with any allowances made to customers.

#### CAPITAL, PROPERTY, AND RESERVE ACCOUNTS.

An account should be provided showing the capital stock outstanding, or the portion of the capital which is used or is available for the working of the business, as well as accounts showing the value of plant, machinery, and real estate. Since there are certain wastages taking place in the operation of a business which are not directly controllable by the management, it is necessary to set up such accounts as "Reserve for depreciation on buildings," "Reserve for depreciation on machinery and equipment," "Reserve for sinking fund," "Reserve for bad debts," and for such other accounts as may be required.

#### RESERVE FOR DEPRECIATION.

It is estimated that the depreciation on a brick building is from 2 to 3 per cent per year and upon a frame building about 5 per cent. Creamery managers, therefore, should be careful to deduct a monthly

charge equal to one-twelfth of the yearly amount computed upon the above basis. These amounts should be charged to "Depreciation on buildings" and credited to "Reserve for depreciation on buildings," and, as in the case of all other expense accounts, the monthly amount should be transferred to the monthly operating statement and there deducted from the gross income. Because of the peculiar nature of the business, the average rate of depreciation on machinery and equipment in creameries should be placed at as high a rate as 15 per cent annually. A reserve for one-twelfth of that amount therefore should be set up monthly and charged against the operating statement. It is essential that a "Reserve for depreciation on machinery" should be set up in order that the plant be kept at its highest efficiency. Poorly kept machinery will often affect the value of the product manufactured and the expense of keeping machinery in proper shape is, therefore, more than offset by the possible loss of income through its depreciation. Reserves for depreciation of property, whether buildings, machinery, or equipment, should be charged with replacements, but ordinary repairs should be charged to the repair account.

#### RESERVE FOR SINKING FUND.

The laws of some States require that cooperative organizations set aside each year a certain percentage of the capital invested to provide a reserve for the retirement of the capital stock. Creameries in those States are obliged to comply with the requirements of the law and to reserve an amount annually in accordance with its provisions. In a large number of creameries, particularly among those located in the State of Minnesota, a reserve is set aside monthly in what is termed a sinking fund. The financial transactions are then divided into a general fund and a sinking fund, the former including all receipts of cash and all disbursements for butter fat, supplies, and operating expense. A sinking fund, as a rule, covers repairs to machinery, taxes, insurance, and dividends on stock, usually termed "Interest on stock." The rate per pound of butterfat for reserve in this way varies from one-fourth of a cent to 1 cent. The purposes for which this fund is established vary greatly, for, while some organizations charge the sinking fund with the items recorded, in others the full amount is applied annually to the interest on and the principal of the indebtedness of the organization, while taxes, insurance, and repairs are prorated over the year and included in operating expenses. In general, it may be recommended that it is better practice to set aside separate reserves for the different forms of depreciation which may occur, since the carrying of many charges in one reserve account may lead to an insufficient amount being set aside to offset the wear and tear on the whole plant. Aside from

the above reserves, it is sometimes desirable to carry the undistributed balance of income, as shown by the operating statement, to the ledger instead of carrying it forward to the head of the next month's operating statement for distribution. Since the undistributed balance is excess income, it can only be considered as an amount of surplus, and therefore can not properly be designated as a reserve, although it may be used as a fund for general purposes not specifically covered by other reserves.

#### CLOSING THE LEDGER.

At the end of the fiscal year the books of the creamery should be closed. In books operated in conformity with the instructions contained in this bulletin, the totals of the income and expense accounts portrayed in the ledger are the result of accumulated credits and debits for the entire yearly period.

A physical inventory should be taken of all property and supply accounts, the value of which should be credited to the inventory accounts in the ledger and carried forward as the balance on hand at the beginning of the year. Should the inventory accounts show a credit balance, it will indicate that the usage charged to such accounts has not been distributed in the proper amounts during the year. The error in distribution either may be charged entirely against the last month or may be prorated as added expense during the months of the following year.

All income and expense accounts should be closed by debiting them with an amount to balance and such amount should be carried to the profit and loss account. If the entire income has been expended during the year, the profit and loss account should balance and there should be no addition to surplus. However, an undistributed balance in the operating statement of the last month is often shown and, in that event, the profit and loss account should show a credit balance of an equal amount. Where an undistributed balance is shown, it may be added to surplus or profit and loss may be debited, and the amount carried forward to the operating statement for the first month of the following year, there to be distributed, together with other income of the month.

In opening the books for the new year, all accounts shown will then be either assets or liabilities, together with surplus, capital, and reserves, the latter representing the net capital of the company.<sup>1</sup>

#### THE OPERATING STATEMENT.

After all entries covering income and expenses have been made in the ledger, the monthly balances of these accounts should be

<sup>1</sup> For further discussion of this subject, see U. S. Department of Agriculture, Office of Markets and Rural Organization, Document No. 2: Lumber Accounting, and Opening the Books in Primary Grain Elevators.



transferred to the operating statement, which is in effect a statement of the income and expense, together with the distribution of the net income. Aside from these entries, the operating statement should record the inventory of butter at the beginning and end of the month. The inventory of butter will include butter in the refrigerator and the inventorable balance of butter on consignment, as shown by the footing of the "Balance on consignment" column of Form 2, the "Record of shipments on consignment." When necessary, inventories of cream, milk, and buttermilk may also be shown, but as a rule this is not done. The addition of the several items of income result in a portrayal of the gross amount distributable. It will be noted that prepaid express, which is express on outbound products, is deducted from the income in order that the net value at the creamery may be shown. By deducting the various expense accounts from the gross amount distributable, the balance for distribution is ascertained. The balance for distribution is used as a basis for figuring the price per pound to be paid for butter fat. The figures representing the distribution to patrons are derived from the totals shown by the various columns of the patrons settlement sheet. Should the amount distributed not equal the balance for distribution there will be a sum left over, which is represented by the "Undistributed balance." After the operating statement is completed, a journal entry should be made in conformity with the example shown below. (See also Form 6, pp. 29-31.)

|                                             | Dr.      | Cr.      |
|---------------------------------------------|----------|----------|
| Butter fat purchased.....                   | \$916.15 |          |
| Current overdrafts.....                     | 5.10     |          |
| To patrons accounts payable.....            |          | \$639.40 |
| Butter, patrons.....                        |          | 187.60   |
| Cream, patrons.....                         |          | 3.20     |
| Cottage cheese, patrons.....                |          | 1.35     |
| Supplies, etc., patrons.....                |          | 4.90     |
| Hauling, patrons.....                       |          | 75.30    |
| Previous overdrafts.....                    |          | 3.20     |
| Undistributed balance.....                  |          | 6.30     |
| (Credit to "Butter fat purchased" account.) |          |          |

It will be noted that butter fat purchased has a debit of \$916.15 which is the amount of the balance for distribution, and a credit of \$6.30. The "Undistributed balance" is journalized and carried to the credit of the "Butter fat purchased" account, in order that the account may show all transactions in butter fat which have taken place during the month. The credit item to this account represents the butter fat value which is undistributed and is therefore subject to distribution in the next month's operation. It has been the custom in some creameries to hold the books open until a date in the succeeding month when sufficient cash was on hand to make payments to patrons. This practice has resulted in considerable confusion

through the predating of cash payments for butter-fat purchases. It is recommended therefore that the amount owed to patrons for butter fat be credited to "Accounts payable patrons" as shown in the journal entry just given, in order that the books may be closed at as early a date as possible, thus assuring that the trial balance and the operating statement agree before actual cash payments are made. When the patron's checks are made out, they should be charged to "Patrons accounts payable," thus closing the account.

PATRON'S VOUCHER.

Postings should be made to the patron's voucher for all incoming products, as represented by the amounts entered on the cream and milk receiving sheets. The amounts to be deducted are derived from the patrons' butter orders and from charges on account for hauling and sundries. After the price per pound has been ascertained, the value of butter fat for each patron computed, and the necessary deductions taken therefrom, the check may be made out and the voucher forwarded to the patron. In case the deductions exceed the amount due the patron, the check should be removed from the statement, and the statement should be mailed to the patron showing the amount of his overdraft. Such overdrafts should be noted in all cases on patrons' vouchers under deductions for the next month.

PATRON'S SETTLEMENT SHEET.

The patron's settlement sheet is a summary of all the credits and debits which have been shown upon the patrons' vouchers. It shows the total pounds of skim milk and butter fat as well as the total deductions on account for various supplies and expenses chargeable to patrons. The price per pound which is to be paid for butter fat is ascertained by dividing the "Balance for distribution" by the total pounds of butter fat. Such a division frequently will give a quotient containing a large fraction and in such cases it usually is found convenient to use only the whole number as the price per pound rather than the actual figure as given by the division. Using this, the total payments to patrons necessarily will be less than the actual balance for distribution. The difference between the two represents the undistributed balance previously referred to under the discussion of the operating statement. The balances remaining after deducting the various expenses chargeable to patrons from the amounts to be distributed, represent the payments to be made by check, or in case the patron has overdrawn his account, the amount of his overdraft. Such overdrafts should be carried forward to the next month's distribution sheet as deductions against the individual patrons to whom they are chargeable. As the debits and credits

should balance, it will be well to prove the sheet by summarizing the totals as in the following example. (See also Form No. 7, p. 32.)

|                                            |           |                               |           |
|--------------------------------------------|-----------|-------------------------------|-----------|
| Butter fat.....                            | \$758. 60 | Payable by check patrons..... | \$639. 40 |
| Skim milk.....                             | 151. 25   | Butter, patrons.....          | 187. 60   |
| Current overdrafts.....                    | 5. 10     | Cream, patrons.....           | 3. 20     |
| (Forwarded to next settle-<br>ment sheet.) |           | Cottage cheese, patrons.....  | 1. 35     |
|                                            |           | Supplies, etc., patrons.....  | 4. 90     |
|                                            |           | Hauling, patrons.....         | 75. 30    |
|                                            |           | Previous overdrafts.....      | 3. 20     |
| Total.....                                 | 914. 95   | Total.....                    | 914. 95   |

After completing the summary, all items excepting those for butter fat and skim milk should be transferred to their proper position on the operating statement under "Distribution to patrons."

#### COMPUTATIONS.

In creameries where both skim-milk and butter fat are purchased and where the skim-milk purchases can be traced to specific patrons, the following computations may be found convenient:

(1) When skim milk is purchased from certain patrons, the book-keeper should determine what percentage of the gross amount distributable is represented by the skim-milk sales and should then divide the "Balance for distribution" on that basis between butter-fat and skim-milk patrons.

(2) To determine the price to be paid for butter fat, divide the amount distributable to butter-fat patrons by the total pounds of butter fat as shown on the patron's settlement sheet.

(3) To determine the price to be paid for skim milk, divide the amount distributable to skim-milk patrons by the total pounds of skim milk as shown on the patron's settlement sheet.

Formulas covering these computations are shown as an appendix to the operating statement.

#### CHANGES NECESSARY UNDER PRIVATE MANAGEMENT.

When this system of accounting is used in creameries operating under private management, it will not be necessary to make up the operating statement except as a statement of income and expenses for the information of the management. If the price of incoming products is ascertained in advance of the sale of manufactured products, no computations will be necessary on the patron's settlement sheet, which would be contingent upon figures derivable from the operating statement. Individual preferences and methods of operating under private management may require other minor changes in the method and technique of bookkeeping as set forth for the operation of this system in cooperative creameries.



### COST ACCOUNTING.

In computing costs of operation, the figures shown on the operating statement will be found adequate in most creameries. If the operations of a creamery include the manufacture of cottage cheese, casein, condensed milk, and other by-products, a cost sheet may be arranged which will show the income from these products and the expenses chargeable to them, together with the comparative percentage ratio of expenses to income. Whether complete cost records are maintained or not, it is advisable that the management keep itself informed as to the comparative cost of operation in the different months, so that leaks or losses due to bad management may be quickly checked up and corrected before results disastrous to the prosperity of the creamery occur. The extent of cost accounting which may be necessary will always depend largely upon the magnitude and diversity of the operations carried on by the organization.

### CONCLUSION.

In this bulletin are outlined briefly the accounting problems of country creameries and a system of accounts which may be adopted uniformly throughout this field of business. Supplementing the information contained herein, the Office of Markets and Rural Organization is prepared to furnish printers' copy of the various forms comprising the system and in so far as practicable to render assistance through its representatives to creameries desiring the installation of the system.







Office of Markets and Rural Organization. Creamery System Form No. 3a.

## CREAM SHEET.

Date, ..... 191 .

| Patron's No. | Pounds cream. | Test. | Pounds fat. | Patron's No. | Pounds cream. | Test. | Pounds fat. | Patron's No. | Pounds cream. | Test. | Pounds fat. | Patron's No. | Pounds cream. | Test. | Pounds fat. |
|--------------|---------------|-------|-------------|--------------|---------------|-------|-------------|--------------|---------------|-------|-------------|--------------|---------------|-------|-------------|
| 1.....       |               |       |             | 26.....      |               |       |             | 51.....      |               |       |             | 76.....      |               |       |             |
| 2.....       |               |       |             | 27.....      |               |       |             | 52.....      |               |       |             | 77.....      |               |       |             |
| 25.....      |               |       |             | 50.....      |               |       |             | 75.....      |               |       |             | 100.....     |               |       |             |
| Total.....   |               |       |             | Total.....   |               |       |             | Total.....   |               |       |             | Total.....   |               |       |             |

Office of Markets and Rural Organization. Creamery System Form No. 3a.

## CREAM SHEET.

Date, ..... 191 .

| Patron's No. | Grade 1.               | Grade 2.             | Patron's No. | Grade 1.               | Grade 2.             | Patron's No. | Grade 1.               | Grade 2.             | Patron's No. | Grade 1.               | Grade 2.             |
|--------------|------------------------|----------------------|--------------|------------------------|----------------------|--------------|------------------------|----------------------|--------------|------------------------|----------------------|
| 1.....       | Pounds cream.<br>Test. | Pounds fat.<br>Test. | 26.....      | Pounds cream.<br>Test. | Pounds fat.<br>Test. | 51.....      | Pounds cream.<br>Test. | Pounds fat.<br>Test. | 76.....      | Pounds cream.<br>Test. | Pounds fat.<br>Test. |
| 2.....       |                        |                      | 27.....      |                        |                      | 52.....      |                        |                      | 77.....      |                        |                      |
| 25.....      |                        |                      | 50.....      |                        |                      | 75.....      |                        |                      | 100.....     |                        |                      |
| Total.....   |                        |                      | Total.....   |                        |                      | Total.....   |                        |                      | Total.....   |                        |                      |











|                                           |       |          |        |
|-------------------------------------------|-------|----------|--------|
| Advanced patrons by supplies.....         | 4.90  |          |        |
| Advanced patrons by hauling.....          | 75.80 |          |        |
| Advanced patrons by prev. overdrafts..... | 3.20  |          |        |
| Advanced patrons by cottage cheese.....   | 1.35  |          |        |
| Advanced patrons by cream.....            | 3.20  |          |        |
| Total advanced to patrons.....            | 4.55  |          | 275.55 |
| Less current overdrafts.....              |       |          | 5.10   |
| Net deductions.....                       |       |          |        |
| Balance payable to patrons.....           |       |          | 270.45 |
| Paid patrons by check.....                |       |          | 645.70 |
| Undistributed balance.....                |       |          | 638.40 |
| (B) Gross amount for distribution.....    |       | 1,120.55 | 6.30   |

## STATISTICS.

## COMPUTATIONS.

|                            |                                 |                                                                                                            |
|----------------------------|---------------------------------|------------------------------------------------------------------------------------------------------------|
| Pounds milk received.....  | Average price paid for fat..... | Using items above marked A, B, C, the following computations may be made:                                  |
| Average test of milk.....  | " " " skim milk.....            | To apportion balance for distribution between butter fat and skim milk patrons, use the following formula: |
| Pounds fat from milk.....  | " " received for butter.....    | $A \times C = D$ which is the amount payable to skim-milk patrons.                                         |
| Pounds cream received..... | Cost per pound.....             | $C - D = E$ , which is the amount payable to butter-fat patrons.                                           |
| Average test of cream..... | Average market quotations.....  |                                                                                                            |
| Pounds fat from cream..... | Profit on by-products.....      |                                                                                                            |
|                            | Five large-d checks.....        |                                                                                                            |
| Total pounds fat.....      |                                 |                                                                                                            |
| Pounds fat sold.....       |                                 |                                                                                                            |
| Pounds fat churned.....    |                                 |                                                                                                            |
| Pounds butter made.....    |                                 |                                                                                                            |
| Pounds overrun.....        |                                 |                                                                                                            |
| Per cent overrun.....      |                                 |                                                                                                            |
| " " moisture content.....  |                                 |                                                                                                            |
| " " salt.....              |                                 |                                                                                                            |
| " " fat in buttermilk..... |                                 |                                                                                                            |

Lbs. skim milk = Price per lb. for skim milk.

E

Lbs. B, F = price per lb. for butter fat.





Office of Markets and Rural Organization. Creamery System Form No. 8.

**BUTTER MAKER'S DAILY RECORD.**

MONTH OF....., 191..

| Date.      | Pounds of milk. | Average test. | Pounds fat in milk. | Pounds of cream. | Average test. | Pounds fat in cream. | Total pounds fat. | Pounds fat sold. | Pounds fat made into butter. | Total butter made. | Pounds of over-run. | Per cent of over-run. | Per cent of moisture. | Per cent of salt. | Per cent of fat in buttermilk. |
|------------|-----------------|---------------|---------------------|------------------|---------------|----------------------|-------------------|------------------|------------------------------|--------------------|---------------------|-----------------------|-----------------------|-------------------|--------------------------------|
| 1.....     |                 |               |                     |                  |               |                      |                   |                  |                              |                    |                     |                       |                       |                   |                                |
| 2.....     |                 |               |                     |                  |               |                      |                   |                  |                              |                    |                     |                       |                       |                   |                                |
| 3.....     |                 |               |                     |                  |               |                      |                   |                  |                              |                    |                     |                       |                       |                   |                                |
| 31.....    |                 |               |                     |                  |               |                      |                   |                  |                              |                    |                     |                       |                       |                   |                                |
| Total..... |                 |               |                     |                  |               |                      |                   |                  |                              |                    |                     |                       |                       |                   |                                |

Office of Markets and Rural Organization. Creamery System Form No. 9.

**BULK AND PRINT BUTTER BALANCE SHEET NO. .... FOR PERIOD FROM  
.....TO.....**

| On hand yesterday. | Made. | Total. | Sold. | Transferred. | On hand to-day. | Total bulk and print. | Shrinkage. | Overage. | Print difference. |
|--------------------|-------|--------|-------|--------------|-----------------|-----------------------|------------|----------|-------------------|
| Bulk 1.....        |       |        |       |              |                 |                       |            |          |                   |
| Print.....         |       |        |       |              |                 |                       |            |          |                   |
| Bulk 2.....        |       |        |       |              |                 |                       |            |          |                   |
| Print.....         |       |        |       |              |                 |                       |            |          |                   |
| Bulk 31.....       |       |        |       |              |                 |                       |            |          |                   |
| Print.....         |       |        |       |              |                 |                       |            |          |                   |
| Total.....         |       |        |       |              |                 |                       |            |          |                   |
| Br't fr'd.....     |       |        |       |              |                 |                       |            |          |                   |
| Grand total.....   |       |        |       |              |                 |                       |            |          |                   |

Notes and other products, etc.:

|                  |  |                                                                           |  |
|------------------|--|---------------------------------------------------------------------------|--|
|                  |  | Office of Markets and Rural Organization.<br>Creamery System Form No. 10. |  |
| .....191..       |  | PLACE.....                                                                |  |
| .....lbs. butter |  | .....CREAMERY Co.                                                         |  |
| .....            |  | Please send me.....pounds                                                 |  |
| .....            |  | of butter and charge to my account.                                       |  |
| .....            |  | No. .... Name.....                                                        |  |
| .....            |  | No butter will be delivered unless accompanied                            |  |
| .....            |  | by order properly signed.                                                 |  |

|                      |       | Office of Markets and Rural Organization. Creamery System Form No. 11.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |        |         |                |              |        |         |                |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|----------------------|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|---------|----------------|--------------|--------|---------|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|                      |       | No. ....                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |        |         |                |              |        |         |                |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|                      |       | .....CREAMERY Co. ....                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |        |         |                |              |        |         |                |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|                      |       | ....., 191 .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |        |         |                |              |        |         |                |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|                      |       | (Address.)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |        |         |                |              |        |         |                |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Sold to .....        |       | .....                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |        |         |                |              |        |         |                |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| .....                |       | .....                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |        |         |                |              |        |         |                |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Line of perforation. |       | <table border="1"> <thead> <tr> <th>Pkgs.</th> <th>Size.</th> <th>Description.</th> <th>Price.</th> <th>Amount.</th> <th>Total charges.</th> </tr> </thead> <tbody> <tr><td>.....</td><td>.....</td><td>.....</td><td>.....</td><td>.....</td><td>.....</td></tr> <tr><td>.....</td><td>.....</td><td>.....</td><td>.....</td><td>.....</td><td>.....</td></tr> <tr><td>.....</td><td>.....</td><td>.....</td><td>.....</td><td>.....</td><td>.....</td></tr> <tr><td>.....</td><td>.....</td><td>.....</td><td>.....</td><td>.....</td><td>.....</td></tr> <tr><td>.....</td><td>.....</td><td>.....</td><td>.....</td><td>.....</td><td>.....</td></tr> <tr><td>.....</td><td>.....</td><td>.....</td><td>.....</td><td>.....</td><td>.....</td></tr> </tbody> </table> |        | Pkgs.   | Size.          | Description. | Price. | Amount. | Total charges. | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Pkgs.                | Size. | Description.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Price. | Amount. | Total charges. |              |        |         |                |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
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No. ....

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....., 191  
(Address.)In account with.....  
(Consignee.).....  
(Address.)

We have shipped you to-day via ..... express or freight the following:

## CONSIGNMENT.

| Commodity. | Containers. | Number. | Net wt. | Total. | Remarks. |
|------------|-------------|---------|---------|--------|----------|
| .....      | .....       | .....   | .....   | .....  | .....    |
| .....      | .....       | .....   | .....   | .....  | .....    |
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# UNITED STATES DEPARTMENT OF AGRICULTURE

## BULLETIN No. 560

OFFICE OF THE SECRETARY

Contribution from the Office of Farm Management.

W. J. SPILLMAN, Chief.

Washington, D. C.



July 9, 1917

## COST OF KEEPING FARM HORSES AND COST OF HORSE LABOR.

A Study of Records for 316 Horses on 27 Farms in Illinois, Ohio, and New York.

By M. R. COOPER, *Scientific Assistant.*

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Inasmuch as horses are the principal source of power on the average farm, the cost of horse labor is of vital concern to the farmer. It has a bearing on the net return of every farm enterprise, yet its significance is not likely to be appreciated fully by one who has not made a study of the subject. This, in large measure, is because the cost of horse labor, unlike that of hired-man labor, is chiefly made up of items of expense representing materials furnished by the farm and not involving a direct cash outlay.

The purpose of this bulletin is to show how the annual cost of keeping a farm work horse and the cost per hour worked may be determined, and to point out that the cost per hour worked is the true measure of the profitableness of a horse to its owner. In other words, it is desired to emphasize the fact that, other things being equal, the horse that costs \$100 a year in feed, shelter, etc., and works 1,000 hours in that time, is more economical than the horse that costs but \$75 for keep and works but 500 hours, since the former costs but 10 cents per hour worked, while the latter costs 15 cents.

NOTE.—This bulletin should be of value to all who are interested in the study of farm-management problems.

## SOURCES OF DATA.

The data presented herein were obtained from cost-accounting records for 316 horses on 27 farms in three States, namely, Illinois, Ohio, and New York. In Illinois and New York the data were obtained by the Office of Farm Management through direct cooperation with the farmers. The Ohio data were obtained in a like manner by the cooperative department of the Ohio Agricultural Experiment Station in cooperation with the Office of Farm Management. The cost records kept on these farms consisted of detailed daily reports of all labor and financial transactions, complete inventories, and other necessary information for determining not only the costs and returns of farm work horses, but also the costs of operation and returns from the entire farm business. (See Table 1.)

TABLE 1.—*Sources of data.*

| State.        | Number of farms studied. | Number of yearly records. | Years for which data were collected. | Total number of horses included. |
|---------------|--------------------------|---------------------------|--------------------------------------|----------------------------------|
| Illinois..... | 10                       | 18                        | 1912-13-14.....                      | 154                              |
| Ohio.....     | 7                        | 16                        | 1909-10-11-12...                     | 72                               |
| New York..... | 10                       | 18                        | 1911-12-13-14...                     | 90                               |
| Total.....    | 27                       | 52                        | .....                                | 316                              |

In Illinois data were procured in the counties of Cass, Menard, and Sangamon. The principal crops raised on the 10 farms studied were corn, oats, wheat, and hay. The live stock fed were hogs and cattle.

The 7 farms in Ohio were located, respectively, in Coshocton, Madison, Adams, Crawford, Greene, Holmes, and Trumbull Counties. The principal crops raised on these farms were corn, oats, wheat, and hay. The live stock fed were hogs and cattle. One farm varied from the others in that dairying and trucking were carried on.

The New York data were collected in the counties of Orleans, Wyoming, Genesee, Monroe, Niagara, and Seneca. The principal crops raised on the 10 farms visited were oats, wheat, beans, potatoes, and hay. Orchardling also was carried on extensively. Little live stock was kept, with the exception that on one farm dairying was followed.

## SUMMARY OF COSTS.

An itemized summary of the annual average cost per horse, and the percentage each item of cost is of the total gross cost, for the horses studied in each State, will be found in Table 2.



TABLE 2.—*Itemized summary of average annual costs and credits per horse, by States (27 farms, 316 horses).*

## GROSS COSTS.

| Item.                               | Illinois (154 horses). |                  | Ohio (72 horses). |                  | New York (90 horses). |                  |
|-------------------------------------|------------------------|------------------|-------------------|------------------|-----------------------|------------------|
|                                     |                        | <i>Per cent.</i> |                   | <i>Per cent.</i> |                       | <i>Per cent.</i> |
| Feed and bedding <sup>1</sup> ..... | \$68.75                | 65.0             | \$76.86           | 58.8             | \$91.25               | 57.1             |
| Labor.....                          | 13.99                  | 13.2             | 27.48             | 21.0             | 22.09                 | 13.8             |
| Interest.....                       | 7.90                   | 7.4              | 3.66              | 6.6              | 9.43                  | 5.9              |
| Stabling.....                       | 4.95                   | 4.7              | 7.18              | 5.5              | 12.98                 | 8.1              |
| Use of equipment.....               | 3.82                   | 3.6              | 5.00              | 3.8              | 5.85                  | 3.7              |
| Shoeing.....                        | .86                    | .8               | 2.35              | 1.8              | 4.56                  | 2.9              |
| Depreciation.....                   | 3.46                   | 3.3              | .....             | .....            | 11.56                 | 7.2              |
| Net loss on colts.....              | .04                    | .....            | 1.24              | 1.0              | .....                 | .....            |
| Miscellaneous.....                  | 2.12                   | 2.0              | 1.90              | 1.5              | 2.09                  | 1.3              |
| Total.....                          | 105.89                 | 100.0            | 130.67            | 100.0            | 159.81                | 100.0            |

## CREDITS.

|                         |        |       |        |       |         |       |
|-------------------------|--------|-------|--------|-------|---------|-------|
| Manure.....             | \$5.24 | ..... | \$8.20 | ..... | \$13.36 | ..... |
| Horse appreciation..... | .....  | ..... | 2.10   | ..... | .....   | ..... |
| Colt profit.....        | .....  | ..... | .....  | ..... | 1.43    | ..... |
| Total.....              | 5.24   | ..... | 10.30  | ..... | 14.79   | ..... |

## NET COST.

|                                    |          |       |          |       |          |       |
|------------------------------------|----------|-------|----------|-------|----------|-------|
| Cost of keeping, less credits..... | \$100.65 | ..... | \$120.37 | ..... | \$145.02 | ..... |
|------------------------------------|----------|-------|----------|-------|----------|-------|

<sup>1</sup> The item of bedding is included with feed, because on many farms straw was used both as a feed and as bedding, and owing to the fact that refuse from the mangers was used for bedding, it was contrary to actual practice to attempt to make bedding a separate item.

The gross costs, made up of the items of feed and bedding, labor, interest, stabling, use of equipment, shoeing, depreciation, loss on colts, and miscellaneous charges, are partially offset by credits for manure, appreciation of young work horses, and profits on colts. The difference between the gross cost and the sum of these credits is the net cost of keeping a horse a year. This is, of course, the cost of the work performed by the horse. It will be seen that, with few exceptions, each item of cost was greater in Ohio than in Illinois, and still greater in New York. This variation in average cost is discussed in the following analysis of the several items of cost and credit.

FEED AND BEDDING.<sup>1</sup>

The term "feed and bedding" includes all grain, roughage, and pasture used by horses. Accurate feed records are difficult to obtain, so that in determining the feed cost shown herein not only the feed records but also the yearly inventories of feeds and the amounts raised and purchased were all considered in arriving at the feed cost.

<sup>1</sup> In the following pages, all references to feed include both feed and bedding.

In each State the feed and bedding costs were more than one-half of the total gross costs of keeping the horses. These costs were about \$69 in Illinois, \$77 in Ohio, and \$91 in New York, varying according to kinds, quantities, and prices of feed and bedding used.

#### KINDS OF FEED.

The number of kinds of feed used were 11 in Illinois, 16 in Ohio, and 18 in New York. In all, there were 26 different kinds. Table 3 shows the feeds used with the quantity and value of each per horse, by States.

TABLE 3.—*Kinds of feed used, average quantity, and value per horse, by States (27 farms, 316 horses).*

| Kind of feed.                        | Illinois (154 horses). |                 | Ohio (72 horses).   |                 | New York (90 horses). |                 |
|--------------------------------------|------------------------|-----------------|---------------------|-----------------|-----------------------|-----------------|
|                                      | Quantity per horse.    | Cost per horse. | Quantity per horse. | Cost per horse. | Quantity per horse.   | Cost per horse. |
| Corn.....bushels..                   | 57.20                  | \$30.90         | 26.50               | \$16.12         | 10.92                 | \$8.36          |
| Oats.....do.....                     | 38.24                  | 13.17           | 53.10               | 22.20           | 42.58                 | 19.94           |
| Hay.....tons.....                    | .77                    | 9.32            | 2.09                | 27.44           | 3.28                  | 43.47           |
| Straw.....do.....                    | 1.06                   | 5.58            | .76                 | 5.43            | 1.38                  | 7.04            |
| Fodder.....do.....                   | .22                    | .56             | .45                 | 1.55            | .03                   | .17             |
| Bran.....pounds.....                 |                        |                 | 85.50               | 1.18            | 184.50                | 2.51            |
| Shorts.....do.....                   |                        |                 | 4.07                | .06             |                       |                 |
| Chop.....do.....                     |                        |                 | 18.70               | .22             |                       | .69             |
| Ground feed.....do.....              |                        |                 |                     |                 | 140.00                | 2.10            |
| Wheat.....bushels.....               |                        |                 |                     |                 | 4.33                  | 3.55            |
| Rye.....do.....                      |                        |                 | .29                 | .24             | .58                   | .47             |
| Barley.....do.....                   |                        |                 |                     |                 | .26                   | .16             |
| Hominy.....pounds.....               |                        |                 |                     |                 | 50.90                 | .66             |
| Oil meal.....do.....                 |                        |                 | 29.50               | .54             | .85                   | .02             |
| Alfalfa meal.....do.....             | 27.35                  | .31             |                     |                 |                       |                 |
| Cottonseed meal.....do.....          |                        |                 | 4.75                | .08             |                       |                 |
| Stock food.....(?).....              | (?)                    | .05             |                     |                 | (?)                   | .09             |
| Oat hay and sheaf oats.....tons..... | .06                    | .71             | .01                 | .07             |                       |                 |
| Sheaf rye.....pounds.....            |                        |                 | 10.40               | .06             |                       |                 |
| Sorghum.....tons.....                |                        |                 | .01                 | .08             | .03                   | .34             |
| Bean pods.....do.....                |                        |                 |                     |                 | .02                   | .12             |
| Silage.....do.....                   | .02                    | .06             |                     |                 |                       |                 |
| Potatoes.....bushels.....            |                        |                 | .41                 | .09             |                       |                 |
| Carrots.....do.....                  |                        |                 |                     |                 | .25                   | .06             |
| Pasture (grass).....months.....      | 4.60                   | 7.36            | 2.26                | 3.50            | 1.13                  | 1.50            |
| Pasture (corn stalks).....do.....    | .33                    |                 |                     |                 |                       |                 |
| All feeds.....                       |                        | 68.75           |                     | 76.86           |                       | 91.25           |

The principal feeds used were corn, oats, hay, straw, and pasture. In Illinois these represented 97 per cent of the total feed cost. In the other two States this percentage was less, being 94.5 in Ohio and 88 in New York. Corn was the principal grain fed in Illinois, oats in Ohio and New York. The greatest quantity of hay per horse was fed in New York, and the most pasture per horse was used in Illinois.

In Illinois very little horse feed was purchased, the concentrate ration being made up primarily of home-grown grains. Corn and oats, with few exceptions, were fed whole. On some farms hay was fed sparingly during idle periods of the year. Straw was used for bedding, and in some cases for feed during the winter months. From

about the middle of April to November the horses were out on grass pasture at night and through the day when not working. In some cases they were pastured on stalk fields after the corn was harvested.

In Ohio a slightly greater quantity of feed per horse was purchased than in Illinois, and less pasture was used, thus necessitating the use of a greater quantity of hay, straw, and other roughage. Corn and oats were sometimes ground and mixed with other feeds that were bought.

In New York a still greater quantity of feed was bought. Often corn and oats were ground, and mixtures of these with purchased feeds were fed. On some farms horses were never pastured. In New York the average time per horse on pasture was 1.13 months, and in Ohio 2.26 months, as against 4.93 months in Illinois. The quantity of hay used increased as the time of pasture decreased.

## COST OF FEEDS.

In Table 4 the feeds are divided into three classes, namely, grain, roughage, and pasture, by States.

TABLE 4.—Average quantity and cost of grain, roughage, and pasture per horse, by States (27 farms, 316 horses).

| Kind of feed.                        | Illinois (154 horses).      |                         | Ohio (72 horses).           |                         | New York (90 horses).       |                         |
|--------------------------------------|-----------------------------|-------------------------|-----------------------------|-------------------------|-----------------------------|-------------------------|
|                                      | Average quantity per horse. | Average cost per horse. | Average quantity per horse. | Average cost per horse. | Average quantity per horse. | Average cost per horse. |
| Grain..... pounds..                  | 4,500                       | \$44.93                 | 3,347                       | \$40.71                 | 2,691                       | \$38.55                 |
| Roughage <sup>1</sup> ..... pounds.. | 4,224                       | 16.13                   | 6,660                       | 32.65                   | 9,513                       | 51.20                   |
| Pasture..... days..                  | 148                         | 7.69                    | 68                          | 3.50                    | 34                          | 1.50                    |
| Total.....                           |                             | 68.75                   |                             | 76.86                   |                             | 91.25                   |

<sup>1</sup> The item "roughage" includes, along with hay, straw, etc., small amounts of succulent roughage, such as silage and roots.

Referring to the figures for the different States, it will be seen that the average total of grain per horse is less in Ohio and New York than in Illinois, while the average total of roughage per horse is greater. This is largely due to the greater relative cost of concentrated feed in the East. Thus the price of corn in New York, as compared with Illinois, is 42 per cent greater, and of oats 36 per cent greater, while the price of hay is only 9 per cent more in New York than in Illinois. In Table 5 is shown the average price of each feed, by States.



TABLE 5.—Average price of each feed, by States (27 farms, 316 horses).

| Kind of feed.                              | Illinois<br>(154<br>horses). | Ohio<br>(72<br>horses). | New<br>York (90<br>horses). |
|--------------------------------------------|------------------------------|-------------------------|-----------------------------|
| Corn.....bushel.....                       | \$0.5403                     | \$0.608                 | \$0.766                     |
| Oats.....do.....                           | .3445                        | .418                    | .4684                       |
| Rye.....do.....                            |                              | .836                    | .810                        |
| Sheaf rye.....hundred weight.....          |                              | .60                     |                             |
| Barley.....bushel.....                     |                              |                         | .615                        |
| Shorts.....hundred weight.....             |                              | 1.50                    |                             |
| Bran.....do.....                           |                              | 1.385                   | 1.36                        |
| Chop.....do.....                           |                              | 1.20                    | 1.82                        |
| Ground feed.....do.....                    |                              |                         | 1.50                        |
| Oil meal.....do.....                       |                              | 1.835                   | 1.80                        |
| Cottonseed meal.....do.....                |                              | 1.56                    |                             |
| Alfalfa meal.....do.....                   | 1.15                         |                         |                             |
| Hominy.....do.....                         |                              |                         | 1.30                        |
| Wheat.....bushel.....                      |                              |                         | .82                         |
| Potatoes.....do.....                       |                              | .22                     |                             |
| Carrots.....do.....                        |                              |                         | .25                         |
| Hay.....ton.....                           | 12.16                        | 13.14                   | 13.27                       |
| Straw.....do.....                          | 5.24                         | 4.50                    | 5.08                        |
| Fodder.....do.....                         | 4.25                         | 3.43                    | 5.00                        |
| Oat hay and sheaf oats.....do.....         | 11.67                        | 10.80                   |                             |
| Sorghum.....do.....                        |                              | 8.00                    | 10.00                       |
| Bean pods.....do.....                      |                              |                         | 7.20                        |
| Silage.....do.....                         | 3.50                         |                         |                             |
| Pasture (grass).....month.....             | 1.60                         | 1.55                    | 1.34                        |
| Pasture (corn stalks).....do.....          | 1.00                         |                         |                             |
| Average price per ton of all grain.....    | 19.97                        | 24.33                   | 28.65                       |
| Average price per ton of all roughage..... | 7.64                         | 9.80                    | 10.76                       |

## PRICES OF FEEDS.

The feed costs given in the foregoing tables are based on the values of feeds at the farm for feeds raised, and on actual cash costs for feeds purchased. These costs for each year were governed somewhat by market prices, and the average value on each farm was influenced by the quality of the feed, and the relative quantity used at different prices.

It will be seen that the average price per bushel of corn in Ohio was \$0.067 higher than the average price in Illinois, and in New York \$0.158 higher than in Ohio. Likewise, the average price per bushel of oats in Ohio was \$0.074 higher than the average price in Illinois, and in New York \$0.05 higher than in Ohio. The average price per ton of hay for Ohio was \$0.98 higher than for Illinois and that for New York \$0.13 higher than that for Ohio.

A comparison of the variations in grain prices in the three States with figures from the Yearbooks of the U. S. Department of Agriculture for the years 1909, 1910, 1911, 1912, and 1913 shows that in Ohio the average farm price per bushel of corn for three years was \$0.046 higher than in Illinois, and in New York \$0.12 higher than in Ohio. Also, these figures show that the average price per bushel of oats for these years was \$0.029 higher in Ohio than in Illinois, and \$0.084 higher in New York than in Ohio. These variations are less than those shown by the figures used in this bulletin. This is partly due to the fact that the prices used in this bulletin are averages for a small number of farms, while those shown in the Yearbooks of the

U. S. Department of Agriculture are averages for each entire State. The grain prices shown in Table 5 are influenced also by the relative quantity of ground corn and oats used in the different States.

It is evident that variation in feed prices had a marked influence on the total feed cost per horse in each State group. Aside from this, a study of individual farms shows that different feeding practices also had a distinct bearing on the total feed cost per horse. On some farms practically the same kinds of grain and roughage were fed throughout the year, the quantities of each varying from month to month according to the amount of work done by the horse. On other farms, the grain fed was reduced, and pasture and cheap roughage, such as straw, fodder, etc., were substituted for hay when the horses were not worked regularly. The fact that the cost of feed was more than half of the total cost of keeping a horse should show how important to every farmer is a careful consideration of this subject.

#### MONTHLY FEED COSTS ON SELECTED FARMS.

In Table 6 are shown the variations in monthly feed costs on three individual farms, one from each of the three States. It will be seen that on each farm the greatest monthly feed costs were for March, April, May, June, and July. For these months, this cost per horse was \$7.47 in Illinois, \$7.60 in Ohio, and \$8.92 in New York; for the remaining seven months, the average monthly feed cost per horse was \$3 less in Illinois, \$1.47 less in Ohio, and \$2.24 less in New York.

TABLE 6.—*Variation in feed costs, by months, on three individual farms located, respectively, in Illinois, Ohio, and New York.*

| Month.         | Illinois. | Ohio.  | New York. |
|----------------|-----------|--------|-----------|
| March.....     | \$8.68    | \$7.75 | \$7.94    |
| April.....     | 7.65      | 7.30   | 7.68      |
| May.....       | 7.34      | 8.42   | 10.39     |
| June.....      | 6.66      | 7.30   | 10.68     |
| July.....      | 7.00      | 7.20   | 7.93      |
| August.....    | 4.70      | 6.50   | 7.76      |
| September..... | 4.58      | 6.66   | 7.53      |
| October.....   | 4.32      | 6.29   | 6.23      |
| November.....  | 4.67      | 5.40   | 6.22      |
| December.....  | 4.40      | 5.70   | 6.56      |
| January.....   | 4.40      | 5.94   | 6.56      |
| February.....  | 4.23      | 6.42   | 5.92      |
| Average.....   | 5.72      | 6.74   | 7.62      |

On this particular Illinois farm the kinds of feed and the quantity of each varied considerably according to the work done by the horse. Especially is this true of the pasture which was used from April to November, when the horses were idle. In this State during December, January, and February corn fodder and straw were fed extensively in the place of hay.

On the Ohio farm, from March to August the feeds used were corn, oats, bran, chop, and hay; from September to January corn

fodder was fed in the place of hay; a part of the time in February hay was again substituted for corn fodder. Straw was used for bedding only.

On the New York farm, corn, oats, rye, and hay were fed throughout the year. Greater quantities of these were fed during May and June, while from October to February there was a marked decrease in the quantities fed. As in Ohio, straw was used for bedding only.

### LABOR COSTS.

"Labor" includes the number of hours of both man and horse labor devoted to feeding and taking care of the horses, cleaning stalls, hauling feed and supplies, and to any other labor performed for the benefit of the horse. The hauling of manure from the barn and barnyards is not charged against the horses, but becomes a part of the manure cost charged to the crop on which it is applied.

TABLE 7.—*Number of hours; cost per hour, and total cost per horse of man and horse labor devoted to the care of horses, by States (27 farms, 316 horses).*

| Kind of labor.   | Illinois (154 horses). |                        |             | Ohio (72 horses). |                        |             | New York (90 horses). |                        |             |
|------------------|------------------------|------------------------|-------------|-------------------|------------------------|-------------|-----------------------|------------------------|-------------|
|                  | Hours.                 | Cost per hour.         | Total cost. | Hours.            | Cost per hour.         | Total cost. | Hours.                | Cost per hour.         | Total cost. |
| Man labor.....   | 85.2                   | <i>Cents.</i><br>14.95 | \$12.74     | 164.6             | <i>Cents.</i><br>16.00 | \$26.34     | 127.3                 | <i>Cents.</i><br>16.40 | \$20.88     |
| Horse labor..... | 13.1                   | 9.56                   | 1.25        | 8.2               | 13.90                  | 1.14        | 8.5                   | 14.22                  | 1.21        |
| Total.....       |                        |                        | 13.99       |                   |                        | 27.48       |                       |                        | 22.09       |

Next after feed, labor was the highest item of cost in caring for the horse, varying from 13 to 21 per cent of the total cost in the three States. Of the labor cost, 94.3 per cent was for man labor. It will be seen that the man-labor cost on the Ohio farms was more than double the cost on those in Illinois, and that on the New York farms it was more than one and one-half times the cost in Illinois. Or, in terms of hours, 85 man-hours per year were devoted on an average to the care of each horse in Illinois, while 127 and 165 hours, respectively, were so devoted in New York and Ohio.

A study of the data shows that on an average each horse in Illinois was pastured a greater number of days than in either of the other States, thus requiring comparatively less attention. On the Ohio and New York farms a number of horses were stabled throughout the entire year, and hence required more attention than those on the farms where pasture was used. It also shows that in Ohio the care of horses on some farms was very high as compared with data on other farms in the three States; hence the high average cost for the farms in this State.



The cost per hour of man labor, as determined from these cost-accounting investigations, was found to be 15 cents for the Illinois farms, 16 cents for those in Ohio, and 16.5 cents for those in New York. The proprietor's labor was charged at the same rates.

The cost per hour of horse labor was found by dividing the net cost of keeping the horses by the total number of hours worked by them. The average cost was about  $9\frac{1}{2}$  cents for the Illinois farms, 14 cents for those in Ohio, and  $14\frac{1}{4}$  cents for those in New York.

#### INTEREST ON VALUE OF HORSES.

Although interest is an indirect cost, it must be considered before the total cost of keeping can be determined. This interest cost was figured at 5 per cent of the average value of the horse as shown by the yearly inventories. In the three States studied, interest varied from an average of \$7.90 in Illinois to \$9.43 in New York. The average values of the horses studied in this work were as follows: Illinois, \$158; Ohio, \$173; New York, \$189.

#### STABLING COST.

"Stabling cost" concerns that part of the buildings used for stabling horses and storing horse feed, and includes 5 per cent interest on the average investment, insurance, taxes, cash and labor, repairs, and depreciation. In cases where records were not kept for a long enough period to determine the depreciation of buildings, a charge of 2 per cent was made, allowance being made for all repairs that were made during the year. This cost varied from 4.7 per cent of the total gross cost of keeping in Illinois to 8.1 per cent in New York.

#### USE OF EQUIPMENT.

This item of cost embraces a charge of 5 per cent interest on the average investment in harness and all miscellaneous equipment used by the horses, both cash and labor for repairs, insurance, taxes, and depreciation. Since this equipment is used by the horses alone, its entire cost should be charged to them. In Illinois this cost was about \$4 per head, and \$1 and \$2 higher in Ohio and New York, respectively.

#### SHOEING.

This item of cost usually represents a direct outlay of cash. On many of the farms this expenditure was of minor importance, since the horses were not shod except when needed for heavy road work or when used on frozen ground. Especially was this true on the Illinois farms, where the average cost per horse was only \$0.86 per year. On the Ohio and New York farms it was much higher, being \$2.35

and \$4.56, respectively, in these States. It is true that on many farms in each State the cost of shoeing individual horses was much greater than the above averages. The fact that on some farms little shoeing was done throughout the year, and on other farms practically the only horses shod were one team for the winter months, would tend to cause a low average cost per horse for each State group.

#### DEPRECIATION AND APPRECIATION.

In determining depreciation and appreciation in value of horses a yearly inventory value was placed on each horse on the farm by careful appraisal and a record was kept of each horse bought or sold. In Illinois 11 of the 18 yearly farm records showed a net depreciation of horses. In Ohio 7 of the 16 yearly records showed a net depreciation, and in New York 16 of the 18 yearly records showed a net depreciation.

The average net depreciation of the 316 horses was \$4.50 per horse.<sup>1</sup> Of this amount \$2.70 per horse was due to the death of 9 horses, valued at \$855. Depreciation varied from \$11.60 per horse in New York to an appreciation of \$2.10 per horse in Ohio.

Table 8 shows the percentage of horses that appreciated in value, the percentage that did not, and the factors influencing the aggregate depreciation or appreciation, by States.

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<sup>1</sup> Bulletin 341 of this department shows that the average annual depreciation of horses on 378 farms studied in Chester County, Pa., is \$7 per head, and on 300 farms studied in Lenawee County, Mich., \$7.10 per head. These figures are largely determined by the practice of farmers in disposing of horses while they are still salable at a fairly satisfactory price, and would undoubtedly be much greater if all farm horses were kept until their usefulness was at an end.

Cornell University (N. Y.) bulletin 377 shows that the average annual depreciation of horses on 14 New York farms for the year 1912, and on 31 New York farms for 1913, was \$14.03 and \$12.10 per horse unit, respectively. Of the 45 farms studied, 12 showed an appreciation of horses.

Minnesota extension bulletin 15, covering a period of four years, 1904 to 1907, inclusive, gives figures for farms studied in three different counties. In Rice County depreciation varied from \$0.98 in 1905 to \$15.48 in 1904, averaging for the four years \$5.56 per head. In Lyon County depreciation varied from \$1.20 in 1905 to \$9.86 in 1904, averaging per year \$6.94 per head. In Norman County depreciation varied from \$2.60 in 1907 to \$7.37 in 1904, averaging per year \$5.82 per head.

It is pointed out in the text that depreciation of the horse is an expensive item to farmers who are not able to control this expense by means of clever selling methods and by the use of young horses. Shrewd selling, however, does not affect the general principal of depreciation, since thus the loss is passed on to the buyer.

Minnesota experiment station bulletin 145 gives results of a further study of horse depreciation in the above-mentioned counties. Records for Rice County for the period 1908 to 1912, inclusive, shows a variation in depreciation from \$0.28 in 1910 to \$5.10 in 1909, and an average per year of \$3.05 per head. In Lyon County the study covers a period of 3 years, 1908 to 1910, inclusive. The depreciation varied from \$1.47 in 1910 to \$5.60 in 1909, averaging per year \$3.06 per head. In Norman County the work covered a period of 4 years, 1908 to 1911, inclusive. The depreciation varied from \$0.51 in 1910 to \$3.42 in 1911, averaging per year \$1.48 per head. It is pointed out in this bulletin that the annual depreciation as shown above is not high enough to represent a proper average charge through a long term of years. Abnormal conditions in the Minnesota horse market were largely responsible for the low depreciation charge.

TABLE 8.—*Percentage of 316 horses that appreciated in value, percentage that did not appreciate, and the factors influencing the aggregate depreciation or appreciation, by States (27 farms, 316 horses).*

| State and number of horses.        | Percentage of horses that showed— |                  | Number of deaths. | Number bought. | Number sold. | Number of colts bought. | Number of colts sold. | Number colts fed. |
|------------------------------------|-----------------------------------|------------------|-------------------|----------------|--------------|-------------------------|-----------------------|-------------------|
|                                    | Appreciation.                     | No appreciation. |                   |                |              |                         |                       |                   |
| Illinois (154 horses).....         | 18.75                             | 81.25            | 3                 | 21             | 21           | 2                       | -----                 | 43                |
| Ohio (72 horses).....              | 21.95                             | 78.05            | -----             | 9              | 17           | 2                       | 1                     | 7                 |
| New York (90 horses).....          | 4.95                              | 95.05            | 6                 | 6              | 3            | 1                       | 2                     | 18                |
| The three States (316 horses)..... | 15.60                             | 84.40            | 9                 | 36             | 41           | 5                       | 3                     | 68                |

On the Illinois and New York farms colts became work horses when from  $2\frac{1}{2}$  to 4 years of age. The age of work horses that depreciated in value varied considerably, depending on their usage and care. The average age of work horses that appreciated in value was about 4 years. The average age of those that neither appreciated nor depreciated in value was about 8 years, and the average age of those that depreciated in value was about 11 years. In Ohio data showing the age of all the horses studied were not obtained; however, the data that were obtained along this line showed about the same results as those in Illinois and New York.

In Illinois about 19 per cent of the horses appreciated in value at the rate of \$36.05 per head per year, while the average depreciation for the other 81 per cent was \$12.55 per head. At this rate it will be seen that a \$36 appreciation of one horse practically would offset the depreciation of three others. Thus the appreciation of one horse out of every 5.34 kept resulted in an average net depreciation for all horses of but \$3.46 per head. Of the 154 horses included in the records from this State 3 died, causing a loss of \$350. In other words, the death loss was about 1 out of every 51. In considering the reason for the number of young horses on these farms and the low depreciation of work horses it was found that there was an average of one colt for every four work horses kept. Further, no colts were sold, all being developed into work horses, 11 becoming work horses during the time in which data were collected. It also will be seen that the same number of horses was bought as was sold. Three died and had to be replaced, and a part of the farmers enlarged their business, thus requiring more horses. With the continued raising and developing of colts into work horses, however, it is safe to say that ordinarily a greater number of young horses will be developed than will be needed in the farm business.

On the Ohio farms about 22 per cent of the horses appreciated in value at the rate of \$56.90 per head. The average depreciation of



the remaining 78 per cent was \$13.30 per head. At this rate the appreciation of 1 horse would offset the depreciation of more than 4 other horses. Thus the appreciation of 1 horse out of every 4.55 resulted in an average net appreciation of \$2.10 per head for the total number of horses. While no deaths occurred in this group, 2 horses were severely injured, entailing a loss of \$175.

On the Ohio farms there was an average of one colt for every 10 work horses kept. This was about two-thirds less than on the Illinois farms, and yet the depreciation of horses was \$5.56 per head less than in Illinois. By this it will be seen that the net appreciation of horses in Ohio was not so much due to the raising of young horses as in Illinois. A study of the data shows that the reason for this was that on some farms a practice was made of buying young horses, and, after working them for a time, selling them at an increase in value. During the years this study was made 9 horses were bought and 17 were sold, 8 of the 17 having been on the farms at the time this work was begun. The horses bought and sold were mostly young draft stock, which accounts for the high appreciation of \$56.90 per horse. In following this practice, at times more horses were kept than were needed to do the farm work. Other data in this bulletin show that the average horse worked less hours per year on the Ohio farms than on the Illinois or New York farms.

On the New York farms the relative number of horses that appreciated in value was a great deal less than in each of the other States—less than 5 per cent—at the rate of \$44.40 per head. The depreciation per head of the remaining 95 per cent was \$14.48. At this rate, the appreciation of one horse would a little more than offset the depreciation of three other horses. Thus, the average net depreciation was \$11.56 for all horses. One reason for this depreciation being higher than in the other two States was a loss of \$505 due to the death of 6 horses, or about 1 out of every 15. Thus, more than 48½ per cent of the total depreciation was due to deaths. The number of colts on these farms was less than in Illinois. For every work horse sold two were bought. It seems that these farmers have but recently started to replace the old horses by raising colts.

#### PROFIT AND LOSS ON COLT ACCOUNT.

In determining these items of loss or credit, young stock were considered as colts from the time they were born until they were broken to work. The cost of keeping the colts on each farm was found by the same method followed in arriving at the cost of keeping work horses. This account was credited with the value of manure produced by the colts and their appreciation in value. It was found that colts usually showed a good profit during the first and second years, and under favorable conditions broke about even for the third

year; that is, the increased cost of keep for the third year was not always covered by the increase in value. Of the 43 colts fed on the Illinois farms, 19 were born during the years this work was done. A loss of 4 cents per head on the Illinois farms was due to the deaths of 4 colts valued at \$300. In Ohio the loss was higher, averaging \$1.24 per head. Of the 7 colts fed, but 1 was born during the period of this work. On the New York farms the colts showed an average profit of \$1.43 per head. No deaths occurred, and of the 18 fed, 8 were born during the years of this work.

Under favorable conditions the raising of colts is one way of keeping down the cost of horse labor. (See fig. 1.)

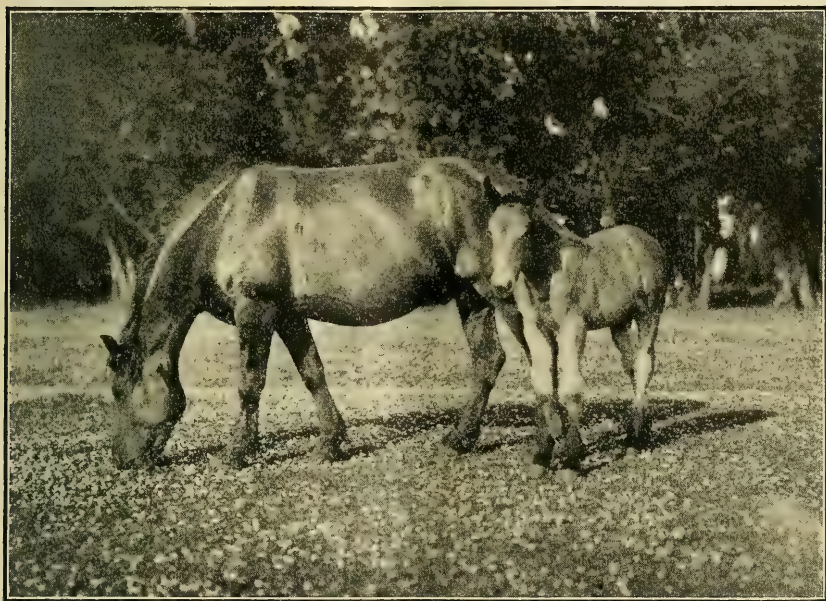


FIG. 1.—Under favorable conditions the raising of colts is one way of keeping down the cost of farm-horse labor.

### MISCELLANEOUS COSTS.

“Miscellaneous costs,” a minor item, embraces insurance, share of taxes, veterinary services and medicine, salt, etc. The average of these costs per head varied from \$1.90 on the Ohio farms to \$2.12 in Illinois. The cost in New York was about the same as that in Illinois. The amount expended for this group of items varies considerably on different farms. The variation is, however, in almost direct proportion to the amount expended for veterinary services.

### MANURE.

Horses were credited with only the manure recovered from the stables and feed lot, which was valued at \$1 per ton before removal.

The amount credited was determined by means of the yearly inventories and a record of the number of tons hauled to the fields.

On the Illinois farms the average manure credit was \$5.24; in Ohio, \$8.20; and in New York, \$13.36 per horse. On individual farms there was a wide variation in the amount of horse manure actually saved. This variation is accounted for to a large extent by the individual practices of manure management, and the extent to which roughage was utilized for feed and bedding purposes.

A study of the average manure credits and their relation to the average amounts of feed used per horse (pp. 3 and 5) shows that the average manure credit per horse is greatest in the States where the horses were fed the greatest quantities of grain and roughage and pastured the least number of days.

### VARIATIONS IN NET COSTS.

In Tables 9, 10, and 11, the data for each State are divided into two groups with reference to net costs. The first group includes those years for which the net cost per horse was greater than the average for the State. The second group includes those years for which the net cost per horse was less than the average for the State.

TABLE 9.—*Illinois farms—Itemized average costs and credits for records showing a net cost per horse above the average for the State, and for those showing a net cost per horse below the average*<sup>1</sup> (10 farms, 154 horses).

| Range of cost.              | Feed<br>(cost). | Labor<br>(cost). | Depreciation<br>(cost). | Appreciation<br>(credit). | Colt<br>loss<br>(cost). | Colt<br>profit<br>(credit). | All<br>other<br>(costs). | Manure<br>(credit). |
|-----------------------------|-----------------|------------------|-------------------------|---------------------------|-------------------------|-----------------------------|--------------------------|---------------------|
| Above the average cost..... | \$78.05         | \$16.20          | \$4.48                  | .....                     | \$3.92                  | .....                       | \$21.02                  | \$5.45              |
| Below the average cost..... | 60.00           | 11.96            | 2.52                    | .....                     | .....                   | \$3.38                      | 18.43                    | 5.06                |
| Difference.....             | 18.05           | 4.24             | 1.96                    | .....                     | 3.92                    | 3.38                        | 2.59                     | .39                 |

<sup>1</sup> Average net cost for the State, \$100.65.

One-half of the 18 yearly farm records showed a net cost greater than the average for all records. The average net cost for this group was \$118.22 per horse, while the average net cost for the nine yearly records with a cost less than the State average was \$84.47, making a difference of \$33.75. Of this difference, \$18.05 was for feed and \$4.24 was for labor. From this it will be seen that the principal difference in cost in this State was for feed, though it naturally follows that a somewhat greater amount of labor will be required for the horses in handling the larger quantities of feed utilized by the better-fed group. The item of depreciation is \$1.96 per horse greater than for the low-cost group. The total death loss of \$350 for all farms was in this group, and it is interesting to note that, had no deaths occurred, the depreciation would have been greater in the low-cost group. In the high-cost group, there was a



net loss of \$3.92 per horse on the colt account, and in the low-cost group a net profit of \$3.38 per horse. This makes a difference between the two groups of \$7.30 per horse. The greater part of this is due to the death of four colts valued at \$300. It will be seen that in addition to the loss of the colts themselves, there was the loss of all feed and attention furnished them. There was a slight difference of 39 cents in the manure credits in favor of the high-cost group.

TABLE 10.—*Ohio farms—Itemized average costs and credits for records showing a net cost per horse above the average for the State, and for those showing a net cost per horse below the average*<sup>1</sup> (7 farms, 72 horses).

| Range of cost.              | Feed<br>(cost). | Labor<br>(cost). | Depre-<br>ciation<br>(cost). | Appre-<br>ciation<br>(credit). | Colt<br>loss<br>(cost). | Colt<br>profit<br>(credit). | All<br>other<br>(costs). | Manure<br>(credit). |
|-----------------------------|-----------------|------------------|------------------------------|--------------------------------|-------------------------|-----------------------------|--------------------------|---------------------|
| Above the average cost..... | \$92. 12        | \$31. 09         | \$0. 07                      | .....                          | \$2. 86                 | .....                       | \$27. 35                 | \$7. 16             |
| Below the average cost..... | 60. 01          | 23. 50           | .....                        | \$4. 50                        | .....                   | \$0. 34                     | 22. 57                   | 9. 25               |
| Difference.....             | 32. 11          | 7. 59            | . 07                         | 4. 50                          | 2. 86                   | . 34                        | 1. 78                    | 2. 19               |

<sup>1</sup> Average net cost per horse for the State, \$120.37.

Variations in costs between the two groups on the Ohio farms were found to be similar to those in Illinois. One-half of the 16 yearly farm records showed a net cost greater than the average for all records. The average net cost per horse for this group was \$146.33, while the average net cost per horse for the low-cost group of eight records was \$91.89. The difference in cost between the two groups was \$54.44, which is \$20.69 greater than the difference in Illinois. Feed and labor made up \$39.70, or 73 per cent of this difference. Here, as in Illinois, it will be seen that these two items are the principal factors controlling variations in cost on the average farm. While there was a slight depreciation per horse in the high-cost group, there was an appreciation of \$4.50 in the low-cost group, making a difference in cost of \$4.57 per horse. Similar conditions were found regarding loss and profit on the colt account; that is, the high-cost group showed an average colt-account loss of \$2.86 per horse, while the low-cost group showed an average profit of 34 cents per horse on this account. The depreciation and appreciation of horses, and the loss and profit on colt accounts, are items worth considering when it is understood that these differences in cost between the two groups were about \$8 per horse. The difference in all other costs between the two groups was \$4.78. This difference was largely due to the higher cost of interest, shoeing, medicine and veterinary services, stabling, and use of equipment in the high-cost group. Other items of cost, such as taxes, insurance, and miscellaneous, were about the same in each group.

There was an average variation in manure credits of \$2.19 per horse, the greatest credit appearing in the low-cost group. This

variation is probably caused by the greater quantities of cheaper roughage fed the horses in this group and due to the fact that the relative amount of manure actually saved varies considerably on different farms by reason of differing methods of manure management.

TABLE 11.—*New York farms—Itemized average costs and credits for records showing a net cost per horse above the average for the State, and for those showing a net cost per horse below the average*<sup>1</sup> (10 farms, 90 horses).

| Range of cost.              | Feed<br>(cost). | Labor<br>(cost). | Depre-<br>ciation<br>(cost). | Appre-<br>ciation<br>(credit). | Colt<br>loss<br>(cost). | Colt<br>profit<br>(credit). | All<br>other<br>(costs). | Manure<br>(credit) |
|-----------------------------|-----------------|------------------|------------------------------|--------------------------------|-------------------------|-----------------------------|--------------------------|--------------------|
| Above the average cost..... | \$95.07         | \$22.76          | \$13.65                      | .....                          | \$0.14                  | .....                       | \$38.54                  | \$12.60            |
| Below the average cost..... | 85.66           | 21.08            | 8.52                         | .....                          | .....                   | \$3.70                      | 29.64                    | 14.50              |
| Difference.....             | 9.41            | 1.68             | 5.13                         | .....                          | .14                     | 3.70                        | 8.90                     | 1.90               |

<sup>1</sup> Average net cost per horse for the State, \$145.02.

Variations in net costs between the two groups in New York were less than those in both Illinois and Ohio. Eleven of the 18 yearly farm records showed a cost per head greater than the average cost for all records. The average net cost per horse for these 18 records was \$157.56, while the average per horse for the remaining 7 records was \$126.70, making a difference between the two groups of \$30.86. Of this difference \$9.41, or less than one-third, was for feed. It will be seen by this that the cost of feeding horses in New York was more nearly uniform than it was in Illinois and Ohio. The difference of \$1.68 for labor also was less in this State. The difference in depreciation cost was \$5.13. A small percentage of this was due to a greater loss from deaths in the first group. The high-cost group showed an average colt loss of 14 cents per horse, and the low-cost group showed an average colt profit of \$3.70 per horse, a difference of \$3.84. There were no deaths of colts in either group. The more colts were raised on the farms in the low-cost group. Colts also showed the cheaper cost of keep and the greater appreciation in value in this group. These items, depreciation and appreciation in the value of horses and loss and profit on colt accounts, were, like those for the Ohio farms, of considerable importance. The total difference in cost of these items between the two groups was \$8.97 per horse. The principal items under "all other costs" causing the difference of \$8.90 per horse were interest, shoeing, stabling, and use of equipment. The difference in manure credits was less than \$2. As on the Ohio farms, the credit was greater in the low-cost group.

#### RELATION OF THE WORK PERFORMED TO THE TOTAL FEED COST.

As previously shown, the greatest item of cost in keeping a farm work horse is for feed. The farmer who gets the maximum amount of work out of his horses, and at the same time has a low feed cost, is reasonably sure of obtaining horse labor at a low cost per hour.

In order to show the relation existing, if any, between the total of work done by a horse and the total cost of feed, the yearly records for each State were divided into two groups with reference to the average total of work done per horse. (See Table 12.) The first group contains the data for those farms on which the horses worked more hours than the average for all records in that State. The second group contains data for those farms on which the hours worked per horse were less than the average for the State group.

TABLE 12.—*Relation of work done to the total feed cost, by States (27 farms, 316 horses).*

| Records with work hours per horse—   | Illinois (154 horses—average hours worked 1,053). |                              |                             | Ohio (72 horses—average hours worked 867). |                              |                             | New York (90 horses—average hours worked 1,020). |                              |                             |
|--------------------------------------|---------------------------------------------------|------------------------------|-----------------------------|--------------------------------------------|------------------------------|-----------------------------|--------------------------------------------------|------------------------------|-----------------------------|
|                                      | Average hours worked per horse.                   | Average feed cost per horse. | Average feed cost per hour. | Average hours worked per horse.            | Average feed cost per horse. | Average feed cost per hour. | Average hours worked per horse.                  | Average feed cost per horse. | Average feed cost per hour. |
| Above the average <sup>1</sup> ..... | 1,200                                             | \$75.20                      | \$0.063                     | 1,055                                      | \$89.00                      | \$0.084                     | 1,172                                            | \$97.30                      | \$0.084                     |
| Below the average <sup>1</sup> ..... | 880                                               | 67.30                        | .077                        | 723                                        | 67.30                        | .093                        | 863                                              | 85.00                        | .098                        |
| Difference.....                      | 320                                               | 7.90                         | .014                        | 332                                        | 21.70                        | .009                        | 309                                              | 12.30                        | .014                        |

<sup>1</sup> The number of records included are as follows: "Above the average" in Illinois 8; in Ohio, 7; in New York 9. "Below the average" in Illinois 9; in Ohio 9; in New York 9.

From this table it will be seen that the average feed cost per horse in each State group was greater for those horses that worked more hours than the average for the group, showing that there is a certain relation between the work done and the quantity of feed consumed per horse. Referring to the average feed cost per hour of labor, it will be seen that the excess in feed cost for the harder-working horses was more than offset by the extra number of hours worked by them, so that the average feed cost per hour of labor in this group was about 1½ cents less on the Illinois and New York farms and about 1 cent less on the Ohio farms. A further study of these factors, together with the relation of the total hours of labor worked to the total cost per hour of horse labor on all farms, is shown in fig. 2. Referring to the lower line and each "X" in this graph, it will be seen that while there was a tendency for the feed cost per hour to decrease as the total hours worked increased, on different farms where the horses worked approximately the same number of hours, there was a wide variation in the average feed cost per hour of labor.

This variation was especially noticeable in the case of those horses that worked from 800 to 900 hours per year. In this group the average feed cost per hour varied on different farms from about 4¼ cents to 11¾ cents. On one farm in the group of horses that worked between 500 and 600 hours, the feed cost per hour was 19 cents. This high cost was due to the fact that the horses were fed heavily on the best of feed throughout the year, though working but few hours per day.



On six farms where the horses worked from about 800 to 1,300 hours per year, the average feed cost per hour was less than 5 cents. This low feed cost per hour was largely due to the judicious use of the cheaper grades of feed and pasture on the farm when the horses did light work or were idle, and to the high number of hours worked per day during the busy crop season when the horses were fed greater quantities and higher-priced feeds. These differences in the feed cost per hour indicate clearly that on many farms the importance of light and heavy feeding and the use of the cheaper feeds, according to the amount of work required, is not fully realized.

Figure 2 further shows that on an average on the farms studied there was a fairly uniform difference between the average feed cost and the total cost per hour of horse labor, showing that the number of hours worked and the feed cost per horse are the controlling factors in the total cost per hour of horse labor.

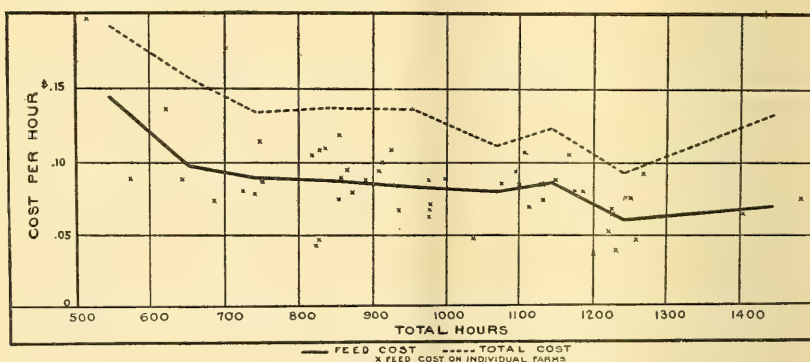


FIG. 2. Relation of total hours worked to feed cost and to total cost per hour of horse labor, for all farms.

### COST OF HORSE LABOR PER HOUR.

The cost of horse labor per hour depends on the net cost yearly to keep a horse, and the total amount of work done. (See Table 13.)

TABLE 13.—*Cost of horse labor per hour (27 farms, 316 horses).*

| State.                     | Average hours worked. |               |             | Average net cost per horse. | Average cost per hour worked. |
|----------------------------|-----------------------|---------------|-------------|-----------------------------|-------------------------------|
|                            | Per year.             | Per week day. | Per Sunday. |                             |                               |
| Illinois (154 horses)..... | 1,053                 | 3.30          | 0.40        | \$100.65                    | Cents. 9.56                   |
| Ohio (72 horses).....      | 866                   | 2.70          | .46         | 120.37                      | 13.90                         |
| New York (90 horses).....  | 1,020                 | 3.24          | .13         | 145.02                      | 14.22                         |

From the averages shown in Table 13 it will be seen that in all cases under consideration the average cost of horse labor is over 9½ cents (on the New York farms over 14 cents), while in no instance

does the average time worked per week day rise above  $3\frac{1}{2}$  hours. It may be noted, as illustrative of the application of these figures, that if the New York and Ohio farmers concerned had hired their horses out at 10 cents per hour, and had failed to work them more than 1,020 and 866 hours per year, respectively, they would have lost on each horse about 4 cents per hour worked.

Of the various ways of keeping down the cost of horse labor, one of the best is to keep the horses busy (see fig. 3).



FIG. 3.—Of the various ways of keeping down the cost of horse labor, one of the best is to keep the horses busy.

#### LABOR PERFORMED, BY MONTHS.

In figure 4 is shown the average work done per horse, by months, for each State group.

Referring to this graph, the general importance of horse labor on these farms for May, June, and July will be seen. In each State very little labor was performed by the horses during January, February, and March. Thereafter the work increased until, during May, the maximum for any one month was reached. From then on to the end of the year there was a fairly uniform decrease in the hours worked per month. In New York and Illinois the increases in October and November are due to grain threshing and corn harvest.

On the Ohio farms, with few exceptions, the average total of labor performed each month was less than on the Illinois and New York farms. Also, it will be noticed that during April, May, November, and December the horses on the Illinois farms worked more hours per

horse than those in New York, while the horses on the New York farms did the greatest amount of work between June and November.

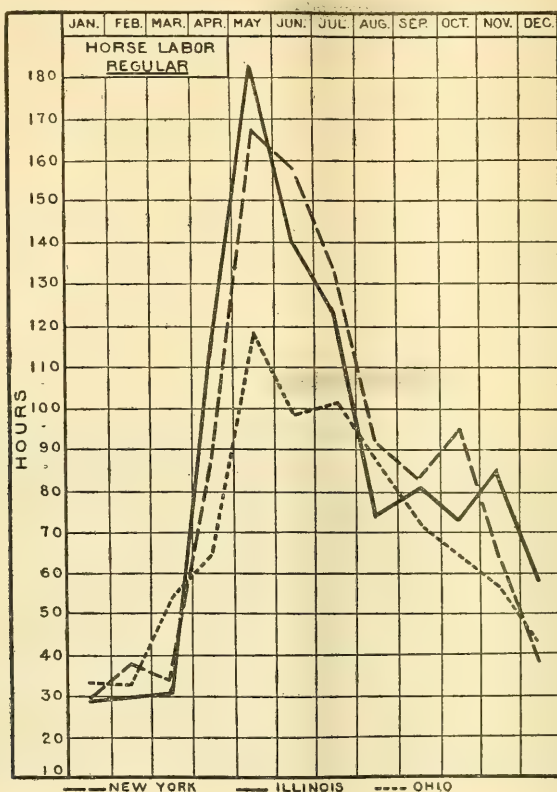


FIG. 4.—Average number of hours worked per horse, by months.

Referring to figure 5, in which is shown the extra horse labor used on the farms studied, it is found that in Illinois the greatest amount of extra horse labor was required during August. In Ohio and New York the greatest amount appears in October. This extra horse labor was usually exchange work among neighbors, the major part being used in grain threshing, corn harvest, and fall seeding.

#### NUMBER OF IDLE WEEK DAYS PER YEAR.

As previously shown, each horse worked approximately three and one-fourth hours per week day on an average throughout the year. There were, however, on all of the farms a few week days in every month when no horse labor was performed. (See Table 14.) In each State over 50 per cent of the total number of week days during which no horse labor was performed are found in the months of January, February, March, and December. For the remainder of the year the week days when no labor was performed varied for different months



and in different States from about 1 day to  $5\frac{3}{4}$  days per month. On an average the horses were idle the fewest days in Illinois and the most in New York. Weather conditions and the farming systems followed were influencing factors in this variation from month to month.

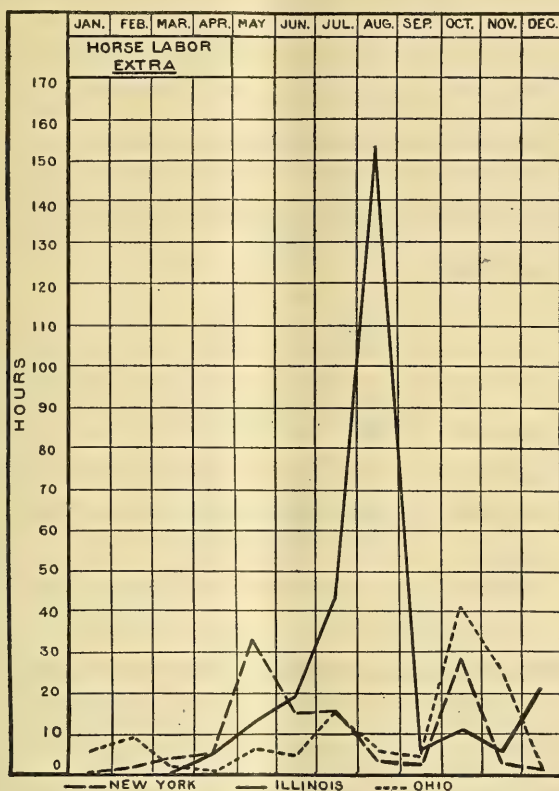


FIG. 5.—Average number of total hours of extra horse labor employed, by months.

TABLE 14.—Average number of week days when no horse labor was performed, by months.

| Month.          | Illinois<br>(10 farms). | Ohio<br>(7 farms). | New York<br>(10 farms). |
|-----------------|-------------------------|--------------------|-------------------------|
| January .....   | 8.3                     | 9.7                | 12.4                    |
| February .....  | 5.8                     | 7.0                | 9.5                     |
| March .....     | 7.0                     | 6.8                | 12.0                    |
| April .....     | 2.7                     | 4.6                | 4.6                     |
| May .....       | 5.0                     | 2.2                | 1.3                     |
| June .....      | 1.1                     | 2.5                | 1.2                     |
| July .....      | 1.2                     | 3.1                | 1.5                     |
| August .....    | 3.8                     | 2.1                | 5.3                     |
| September ..... | 3.0                     | 4.0                | 3.5                     |
| October .....   | 3.5                     | 5.4                | 4.8                     |
| November .....  | 1.9                     | 3.5                | 5.8                     |
| December .....  | 5.1                     | 7.6                | 11.3                    |
| Total .....     | 48.4                    | 58.5               | 73.2                    |

## RELATION OF TOTAL CROP ACRES PER FARM TO CROP ACRES PER HORSE.

It has been shown that on an average the feed cost and total cost per hour of horse labor on the farms studied decreased as the number of hours worked per horse increased. The amount of work required per horse depends on the size of the business and the number of horses on the farm. On most of the farms included in this study the size of the business depended largely on the number of crop acres in the farm; that is, acres under cultivation. It is true that a great deal of horse labor other than crop labor was performed on these farms, but it is safe to say that in every case the horses required to tend the crops during the crop season could easily do all other necessary labor.

The relation of crop acres per farm to crop acres per horse is shown in Table 15, by States.

TABLE 15.—*Relation of total crop acres per farm to crop acres per horse, by States (27 farms, 316 horses).*

| Farms.                            | Illinois (10 farms—<br>average size, 166 acres). |                       | Ohio (7 farms—<br>average size, 74 acres). |                       | New York (10 farms—<br>average size, 94 acres). |                       |
|-----------------------------------|--------------------------------------------------|-----------------------|--------------------------------------------|-----------------------|-------------------------------------------------|-----------------------|
|                                   | Average<br>per farm.                             | Average<br>per horse. | Average<br>per farm.                       | Average<br>per horse. | Average<br>per farm.                            | Average<br>per horse. |
|                                   | <i>Acres.</i>                                    | <i>Acres.</i>         | <i>Acres.</i>                              | <i>Acres.</i>         | <i>Acres.</i>                                   | <i>Acres.</i>         |
| Farms above the average size..... | 230.2                                            | 22.2                  | 93.7                                       | 17.8                  | 112.74                                          | 20                    |
| Farms below the average size..... | 111.2                                            | 16.8                  | 54.7                                       | 14.6                  | 70.07                                           | 17                    |
| Difference.....                   | 119.0                                            | 5.4                   | 39.0                                       | 3.2                   | 42.67                                           | 3                     |

From these figures it appears that the large farms permit of a more efficient use of horse labor than do the small farms. On the large farms in Illinois there were 22.2 acres in crops per horse, while on the small farms there were but 16.8 acres per horse. Similar results were found on both the Ohio and the New York farms, though in these States the difference between the two groups was not as great as in Illinois.

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# UNITED STATES DEPARTMENT OF AGRICULTURE



## BULLETIN No. 561

Contribution from the Bureau of Animal Industry  
A. D. MELVIN, Chief



Washington, D. C.



August 18, 1917

### FEED COST OF EGG PRODUCTION.

#### RESULTS OF THREE YEARS' EXPERIMENTS AT THE GOVERNMENT POULTRY FARM.

By HARRY M. LAMON and ALFRED R. LEE,

*Of the Animal Husbandry Division.*

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#### OBJECTS OF THE WORK.

Complete data on the feed cost of egg production for fowls kept on free range or on conditions somewhat similar to those existing on general farms are very limited. The main object of the experiments reported in this bulletin was to compare the results obtained through the use of simple rations and methods and to record the feed cost of egg production under these conditions. Only the feed costs are considered, because most of the pens were on free range, scattered over a wide area to keep the fowls from mixing, which, with the keeping of records, weighing the eggs and grain, etc., involved much work which would be unnecessary under commercial conditions. Careful observations were made of the conditions which affect egg production, such as molting and broodiness, and detailed records were kept of the feed used and of the weight of the eggs. These experiments were started in the fall of 1912 with six pens of 30 pullets each. New pens

have been added each year subsequently, and the original pens are still being kept to study the effect of the feed and of the age of the fowls on egg production. The results secured in 16 pens, containing 366 fowls, are given in this bulletin, including three complete years' work of the first six pens. The work was conducted on the experimental farm of the Bureau of Animal Industry, near Beltsville, Md. Prices of individual grains in 1917 are from 20 to 100 per cent higher than the prices used in this bulletin, which should be carefully considered in estimating the present cost of egg production.

### DESCRIPTION OF STOCK AND CONDITIONS.

Most of the feeding tests were started with 30 standard-bred pullets, bred and reared on the farm under the same conditions, and selected for vigor, standard shape, and color. Some of the flocks consisted of fowls of one breed, while others contained more than one kind of pure-bred fowls of the general-purpose type in the same flock, including Barred Plymouth Rocks, White Wyandottes, Rhode Island Reds, and Buff Orpingtons (see Plates I to IV). Pens 10 to 14, inclusive, also contained some cross-bred pullets. These flocks were housed in colony houses similar to those shown in Plates III and V. The house shown in Plate III is 10 feet long by 7 feet wide, and that in Plate V is 6 feet long by 5 feet wide; both houses are described in detail in Farmers' Bulletin 574 of this department. A better average result is secured by using 30 fowls in each pen than is obtained from smaller flocks, as the effect of any variation due to individuals is reduced greatly. Except three pens which were confined to good-sized yards, all the fowls were allowed free range over several acres of rough land, part of which is in woods and the rest is covered with grass and weeds. The soil is a heavy clay, which does not drain freely.

TABLE 1.—*Pens, rations, and conditions.*

| Pen No. | Date experiment began. | Number of pullets. | Breed.                                                                                    | How kept.    | Feed.                                                                |                                                                                                 |
|---------|------------------------|--------------------|-------------------------------------------------------------------------------------------|--------------|----------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
|         |                        |                    |                                                                                           |              | Scratch mixture.                                                     | Mash.                                                                                           |
| 1       | Nov. 1, 1912           | 30                 | Rhode Island Reds..                                                                       | Free range.. | $\frac{1}{2}$ cracked corn, $\frac{1}{4}$ wheat, $\frac{1}{4}$ oats. | $\frac{1}{2}$ bran, $\frac{1}{4}$ middlings, $\frac{1}{4}$ corn meal, $\frac{1}{4}$ beef scrap. |
| 2       | .....do.....           | 30                 | 21 White Wyandottes, 6 Buff Orpingtons, 3 Barred Plymouth Rocks.                          | .....do..... | $\frac{1}{2}$ cracked corn, $\frac{1}{2}$ wheat.                     | Same as for Pen 1.                                                                              |
| 3       | .....do.....           | 30                 | 14 Buff Orpingtons, 16 Rhode Island Reds.                                                 | Yarded.....  | Same as for Pen 1.                                                   | Bran, middlings, corn meal, and beef scrap, each in separate hoppers.                           |
| 4       | Jan. 18, 1913          | 30                 | White Leghorns.....                                                                       | Free range.. | .....do.....                                                         | Same as for Pen 3.                                                                              |
| 5       | .....do.....           | 30                 | 19 Barred Plymouth Rocks, 2 White Plymouth Rocks, 6 Rhode Island Reds, 3 Buff Orpingtons. | Yarded.....  | .....do.....                                                         | 9 per cent bran, 9 per cent middlings, 63 per cent corn meal, 19 per cent beef scrap.           |



TABLE 1.—*Pens, rations, and conditions*—Continued.

| Pen No. | Date experiment began. | Number of pullets. | Breed.                                                                                                                           | How kept.    | Feed.                                                                                      |                                                                                                            |
|---------|------------------------|--------------------|----------------------------------------------------------------------------------------------------------------------------------|--------------|--------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|
|         |                        |                    |                                                                                                                                  |              | Scratch mixture.                                                                           | Mash.                                                                                                      |
| 6       | Jan. 25, 1913          | 30                 | 11 Barred Plymouth Rocks, 1 White Plymouth Rock, 3 White Orpingtons, 3 Buff Orpingtons, 9 White Wyandottes, 3 Rhode Island Reds. | Free range.. | $\frac{1}{4}$ cracked corn, $\frac{1}{4}$ wheat, $\frac{1}{4}$ oats, $\frac{1}{4}$ barley. | Beef scrap and a mixture of equal parts corn meal and middlings in separate hoppers.                       |
| 7       | Dec. 1, 1913           | 30                 | White Leghorns.....                                                                                                              | Yarded.....  | Same as for Pen 1                                                                          | Same as for Pen 3.                                                                                         |
| 8       | .....do.....           | 30                 | White Leghorns.....                                                                                                              | Free range.. | .....do.....                                                                               | 4 per cent bran, 4 per cent middlings, 66 per cent corn meal, 26 per cent beef scrap.                      |
| 9       | .....do.....           | 30                 | 9 Barred Plymouth Rocks, 2 White Plymouth Rocks, 11 Buff Orpingtons, 8 Rhode Island Reds.                                        | .....do..... | .....do.....                                                                               | $\frac{1}{4}$ bran, $\frac{1}{4}$ middlings, $\frac{1}{2}$ corn meal.                                      |
| 10      | Nov. 1, 1914           | 8                  | 4 Rhode Island Reds, 3 Crosses, 1 Barred Plymouth Rock.                                                                          | .....do..... | .....do.....                                                                               | 3 parts bran, 1 part middlings, 2 parts corn meal, 3 parts cottonseed meal.                                |
| 11      | .....do.....           | 8                  | 4 Rhode Island Reds, 3 Crosses, 1 Barred Plymouth Rock.                                                                          | .....do..... | .....do.....                                                                               | 2 parts bran, 1 part middlings, 2 parts corn meal, $\frac{1}{2}$ part beef scrap, 2 parts cottonseed meal. |
| 12      | .....do.....           | 8                  | 5 Rhode Island Reds, 2 Crosses, 1 Barred Plymouth Rock.                                                                          | .....do..... | .....do.....                                                                               | Same as Pen 8.                                                                                             |
| 13      | Jan. 19, 1915          | 18                 | 7 Rhode Island Reds, 6 Crosses, 3 Barred Plymouth Rocks, 2 Buff Orpingtons.                                                      | .....do..... | .....do.....                                                                               | 1 part bran, 1 part middlings, 2 parts corn meal, 1 part fish meal.                                        |
| 14      | .....do.....           | 18                 | 6 Rhode Island Reds, 8 Crosses, 2 Buff Orpingtons, 2 Barred Plymouth Rocks.                                                      | .....do..... | .....do.....                                                                               | 1 part bran, 1 part middlings, 2 parts corn meal, 1 part beef scrap.                                       |
| 15      | Mar. 2, 1915           | 24                 | 13 White Leghorns, 11 Barred Plymouth Rocks.                                                                                     | .....do..... | .....do.....                                                                               | Same as Pen 10.                                                                                            |
| 16      | .....do.....           | 12                 | 7 Barred Plymouth Rocks, 5 White Leghorns.                                                                                       | .....do..... | .....do.....                                                                               | Same as Pen 11.                                                                                            |

All parts are by weight.

## METHODS OF FEEDING.

The scratch mixture of whole or cracked grains was fed twice daily in 2 to 3 inches of straw litter on the floor of each pen, feeding about one-third of the grain in the morning and the rest at night. Hoppers containing a dry mash, or mixture of ground grains, were kept open before the fowls all the time. The amount of the scratch mixture was fixed during 1912 and 1913 so that the fowls ate about one-third mash and two-thirds grain. As there appeared to be a tendency for all the hens except the Leghorns to become too fat and not exercise enough under this method, the amount of scratch grains was reduced in 1914 so that the hens ate about equal parts of the

grains and of the mash. This is the method of feeding now being used and appears to be a good one to follow. Coarse grit and oyster shell were fed on the ground near the houses, and green feed was supplied to the pens not having free range. The pens were put into the experiment as soon as the pullets were mature, except Pens 13, 14, 15, and 16, which were started on special tests some time after the pullets had matured and started to lay. The time of maturity materially affects the egg yields of fowls during their pullet year, and should be considered in comparing Pens 4, 5, and 6, in Table 2 (first year) with the other pens. The following regular records were kept for each pen: A daily record of the number and weight of the eggs; a weekly feed record of the grain, mash, and green feed; and a monthly record of the weight of each hen. All rations are by weight.

TABLE 2.—Average egg yield and feed cost per hen, weight of eggs, etc.

## FIRST YEAR, PENS 1 TO 6.

| Pen No.      | Average egg yield per hen. | Feed per hen. |        | Feed per dozen eggs. |        | Average value of eggs per hen over feed cost. | Average weight per dozen eggs. | Number times hens broody. | Number hens died, etc. |
|--------------|----------------------------|---------------|--------|----------------------|--------|-----------------------------------------------|--------------------------------|---------------------------|------------------------|
|              |                            | Lbs.          |        | Lbs.                 | Cents. |                                               | Pounds.                        |                           |                        |
| 1.....       | 142.2                      | 74            | \$1.17 | 6.24                 | 9.89   | \$2.86                                        | 1.58                           | 56                        | 4                      |
| 2.....       | 145.1                      | 59            | .94    | 4.87                 | 7.74   | 3.26                                          | 1.55                           | 70                        | 4                      |
| 3.....       | 125.6                      | 73            | 1.16   | 7.00                 | 10.90  | 2.50                                          | 1.54                           | 94                        | 5                      |
| 4.....       | 137.8                      | 55            | .87    | 4.68                 | 7.34   | 2.72                                          | 1.42                           | 0                         | 5                      |
| 5.....       | 121.7                      | 75            | 1.16   | 7.34                 | 11.24  | 2.17                                          | 1.54                           | 111                       | 3                      |
| 6.....       | 118.0                      | 81            | 1.33   | 8.10                 | 13.18  | 1.88                                          | 1.53                           | 68                        | 5                      |
| Average..... | 131.7                      | 70            | 1.11   | 6.37                 | 10.00  | 2.56                                          | 1.53                           | 67                        | 4.3                    |

## SECOND YEAR, PENS 1 TO 6.

|              |       |    |        |      |      |        |      |    |     |
|--------------|-------|----|--------|------|------|--------|------|----|-----|
| 1.....       | 92.9  | 69 | \$1.07 | 9.2  | 14.4 | \$1.25 | 1.65 | 46 | 7   |
| 2.....       | 78.2  | 59 | .95    | 9.2  | 14.6 | 1.08   | 1.59 | 44 | 3   |
| 3.....       | 77.8  | 67 | 1.03   | 10.3 | 16.0 | 1.08   | 1.62 | 74 | 0   |
| 4.....       | 115.9 | 54 | .85    | 5.6  | 8.7  | 2.18   | 1.50 | 4  | 3   |
| 5.....       | 100.3 | 73 | 1.15   | 8.6  | 13.5 | 1.67   | 1.60 | 82 | 6   |
| 6.....       | 91.1  | 83 | 1.32   | 10.6 | 16.9 | 1.22   | 1.62 | 66 | 4   |
| Average..... | 92.7  | 68 | 1.06   | 8.9  | 14.0 | 1.41   | 1.60 | 62 | 3.8 |

## FIRST YEAR, PENS 7 TO 9.

|              |       |    |        |     |      |        |      |       |     |
|--------------|-------|----|--------|-----|------|--------|------|-------|-----|
| 7.....       | 120.9 | 56 | \$0.88 | 5.6 | 8.7  | \$2.45 | 1.46 | 2     | 1   |
| 8.....       | 157.6 | 56 | .88    | 4.2 | 6.7  | 3.41   | 1.47 | 7     | 4   |
| 9.....       | 90.0  | 61 | .88    | 8.2 | 11.7 | 1.55   | 1.50 | 76    | 2   |
| Average..... | 122.8 | 58 | .88    | 6.0 | 9.0  | 2.47   | 1.48 | ..... | 2.3 |

## THIRD YEAR, PENS 1 TO 6.

|              |       |    |        |      |      |        |      |    |     |
|--------------|-------|----|--------|------|------|--------|------|----|-----|
| 1.....       | 71.4  | 82 | \$1.31 | 14.1 | 22.4 | \$0.39 | 1.75 | 25 | 5   |
| 2.....       | 59.4  | 75 | 1.23   | 16.0 | 26.0 | .11    | 1.66 | 27 | 3   |
| 3.....       | 59.9  | 65 | .97    | 13.1 | 19.5 | .65    | 1.61 | 47 | 5   |
| 4.....       | 112.1 | 56 | .84    | 6.0  | 8.8  | 1.94   | 1.49 | 2  | 5   |
| 5.....       | 82.9  | 76 | 1.19   | 11.0 | 17.2 | .95    | 1.63 | 46 | 0   |
| 6.....       | 83.4  | 90 | 1.40   | 12.9 | 20.0 | .71    | 1.62 | 32 | 1   |
| Average..... | 78.2  | 74 | 1.16   | 12.2 | 19.0 | .79    | 1.63 | 30 | 3.2 |

TABLE 2.—Average egg yield and field cost per hen, weight of eggs, etc.—Continued.

SECOND YEAR, PENS 7 TO 9.

| Pen No. | Average egg yield per hen. | Feed per hen. |        | Feed per dozen eggs. |        | Average value of eggs per hen over feed cost. | Average weight per dozen eggs. | Number times hens broody. | Number hens died, etc. |
|---------|----------------------------|---------------|--------|----------------------|--------|-----------------------------------------------|--------------------------------|---------------------------|------------------------|
|         |                            | Lbs.          |        | Lbs.                 | Cents. |                                               |                                |                           |                        |
| 7.....  | 107.0                      | 56            | \$0.84 | 6.2                  | 9.4    | \$1.92                                        | 1.46                           | 7                         | 0                      |
| 8.....  | 151.8                      | 59            | .93    | 4.7                  | 7.5    | 2.81                                          | 1.52                           | 1                         | 5                      |
| 9.....  | 84.3                       | 74            | 1.07   | 10.7                 | 15.3   | 1.07                                          | 1.56                           | 43                        | 6                      |

FIRST YEAR, PENS 10 TO 16.

|         |       |    |        |      |      |        |      |    |   |
|---------|-------|----|--------|------|------|--------|------|----|---|
| 10..... | 103.8 | 74 | \$1.10 | 9.0  | 13.4 | \$1.39 | 1.59 | 14 | 2 |
| 11..... | 102.3 | 69 | 1.01   | 7.9  | 11.9 | 1.53   | 1.56 | 6  | 2 |
| 12..... | 169.5 | 89 | 1.44   | 6.3  | 10.2 | 3.14   | 1.54 | 17 | 0 |
| 13..... | 145.4 | 68 | 1.02   | 5.6  | 8.5  | 2.96   | 1.51 | 36 | 0 |
| 14..... | 160.0 | 84 | 1.32   | 6.2  | 9.7  | 3.03   | 1.47 | 22 | 2 |
| 15..... | 33.2  | 62 | .91    | 21.4 | 31.9 | .04    | 1.37 | 2  | 9 |
| 16..... | 67.6  | 60 | 1.04   | 12.0 | 18.0 | .63    | 1.45 | 10 | 4 |

This table is arranged consecutively according to the year that the experiment was conducted.

The averages of pens 7 to 16 are not included because deficient rations were fed in several of these pens, making such averages of no value.

Missing hens and those killed by hawks are included with the hens that died (last column of table) as follows: Second year, missing, one from Pen 1, two from Pen 2, one from Pen 4, and one from Pen 6; killed by hawks, one from Pen 4, and two from Pen 8; third year, missing or killed by hawks, two from Pen 4, three from Pen 8, two from Pen 9, one from Pen 10, four from Pen 15, and two from Pen 16.

The cost of the green feed which was fed in the yarded pens (Nos. 3, 5, and 7) is not included in this table. It amounts to about 10 cents per hen, or 1 cent per dozen eggs (see p. 18). All costs throughout this bulletin are figured on the basis of feed only and do not include labor or any other items.

The general-purpose breeds ate an average of about 70 pounds of both grain and mash per head in one year, while the Leghorns consumed about 55 pounds per head. On this basis, if their feed is regu-

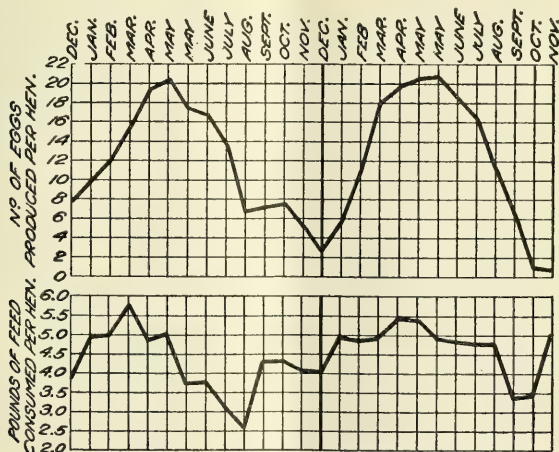


FIG. 1.—Average egg yield and feed consumption per hen in Pen 8 for 2 years by 4-week periods. (This necessitates repetition of month of May so as to make 13 periods in the year.)

lated so that the hens will eat equal parts of scratch grains and of mash, 100 fowls of the general-purpose breeds should be fed about



9.5 pounds each of grain and of mash daily, and 100 Leghorns should receive about 7.5 pounds of each. (See Table 3 for amount in quarts.) The amount of feed consumed varies considerably throughout the year, being greatest just preceding the period of highest egg production, but it does not vary absolutely with production either during one year or when one year is compared with another. (See fig. 1.) This latter fact is readily seen by comparing the average egg yield and total feed consumption in Pens 1 to 6 for their first and second years (see Table 2). The egg yield decreased about 30 per cent in their second year, while the feed consumption decreased only 3 per cent.

A fair grade of beef scrap with a guaranteed protein analysis of 50 to 55 per cent, fat 12 to 13 per cent, and 1 to 3 per cent of fiber was used. The cracked corn was white, but the corn meal was ground from yellow corn. The prices of some of the grains were changed in April, 1913, to conform to the market price at that time. That price has since been used without change in figuring all the costs in this bulletin. Prices of individual grains in 1917 are from 20 to 100 per cent higher than the prices used in this bulletin. Present prices of grains should be compared to these prices in arriving at the present cost of producing eggs.

TABLE 3.—*Price and weight of grains.*

| Grain.               | Price per 100 pounds.    |                          | Price per bushel.        |                          | Weight of<br>1 quart. |       |
|----------------------|--------------------------|--------------------------|--------------------------|--------------------------|-----------------------|-------|
|                      | Up to<br>April,<br>1913. | After<br>April,<br>1913. | Up to<br>April,<br>1913. | After<br>April,<br>1913. |                       |       |
| Cracked corn.....    | \$1.30                   | \$1.20                   | \$0.73                   | \$0.67                   | Lbs.                  | Oz.   |
| Wheat.....           | 1.90                     | 1.79                     | 1.14                     | 1.07                     | 1                     | 12    |
| Oats.....            | 1.60                     | 1.34                     | .51                      | .43                      | 1                     | 14    |
| Barley.....          | 1.74                     | 1.74                     | .84                      | .84                      | 1                     | 8     |
| Corn meal.....       | 1.35                     | 1.45                     | .65                      | .70                      | 1                     | 8     |
| Wheat bran.....      | 1.40                     | 1.40                     | .....                    | .....                    | .....                 | 10    |
| Wheat middlings..... | 1.45                     | 1.37                     | .....                    | .....                    | .....                 | 13    |
| Fish meal.....       | .....                    | 2.30                     | .....                    | .....                    | .....                 | ..... |
| Beef scrap.....      | 2.50                     | 2.65                     | .....                    | .....                    | 1                     | 5     |
| Cottonseed meal..... | .....                    | 1.85                     | .....                    | .....                    | .....                 | ..... |
| Grit.....            | .60                      | .60                      | .....                    | .....                    | .....                 | ..... |
| Oyster shell.....    | .60                      | .60                      | .....                    | .....                    | .....                 | ..... |

#### HENS BALANCING THEIR OWN RATIONS.

The fowls in Pens 3, 4, and 7 had bran, middlings, corn meal, and beef scrap in separate hoppers before them all the time (see Table 1). Tables 4, 4a, 4b, and 4c show the proportion of these mash feeds eaten by these pens for each 4-week period.

TABLE 4.—Percentage of mash feeds consumed each 4-week period (Pens 3 and 4, first year).

| Period.                     | Corn meal.       |                  | Beef scrap.      |                  | Bran.            |                  | Middlings.       |                  |
|-----------------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
|                             | Pen 3.           | Pen 4.           | Pen 3.           | Pen 4.           | Pen 3.           | Pen 4.           | Pen 3.           | Pen 4.           |
| 1912.                       | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> |
| November.....               | 55               |                  | 30               |                  | 6                |                  | 9                |                  |
| December.....               | 61               |                  | 15               |                  | 10               |                  | 14               |                  |
| 1913.                       |                  |                  |                  |                  |                  |                  |                  |                  |
| January.....                | 70               | 67               | 13               | 27               | 8                | 4                | 9                | 2                |
| February.....               | 72               | 65               | 17               | 30               | 7                | 2                | 4                | 3                |
| March.....                  | 61               | 76               | 21               | 19               | 7                | 3                | 11               | 2                |
| April.....                  | 66               | 63               | 15               | 27               | 9                | 5                | 10               | 5                |
| May.....                    | 67               | 65               | 23               | 26               | 4                | 4                | 6                | 5                |
| May 1.....                  | 64               | 63               | 20               | 25               | 10               | 6                | 6                | 6                |
| June.....                   | 50               | 67               | 19               | 25               | 16               | 6                | 15               | 2                |
| July.....                   | 49               | 54               | 24               | 29               | 13               | 10               | 14               | 7                |
| August.....                 | 55               | 54               | 22               | 33               | 9                | 6                | 13               | 7                |
| September.....              | 60               | 57               | 21               | 29               | 10               | 7                | 9                | 7                |
| October.....                | 60               | 65               | 21               | 27               | 9                | 4                | 10               | 4                |
| November <sup>2</sup> ..... | (52)             | 65               | (25)             | 19               | (12)             | 8                | (11)             | 8                |
| December.....               | (71)             | 58               | (18)             | 33               | (3)              | 4                | (8)              | 5                |
| Average.....                | 63               | 63.7             | 19               | 27               | 9                | 4.9              | 9                | 4.4              |

<sup>1</sup> In this and other tables the year is divided into 13 periods of 4 weeks each, consequently the periods only represent in general the months indicated and thus it is necessary to show two periods in one month during the year (May). The actual dates of these periods for each pen are given in the text following Table 4c.

<sup>2</sup> Figures in parentheses belong to the following year's record and are inserted here to make the monthly comparisons complete; they are not included in the year's average.

TABLE 4a.—Percentage of mash feeds consumed each 4-week period (second year for Pens 3 and 4, first year for Pen 7).

| Period.        | Corn meal.    |               |               | Beef scrap.   |               |               | Bran.         |               |               | Middlings.    |               |               |
|----------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
|                | Pen 3.        | Pen 4.        | Pen 7.        | Pen 3.        | Pen 4.        | Pen 7.        | Pen 3.        | Pen 4.        | Pen 7.        | Pen 3.        | Pen 4.        | Pen 7.        |
| 1913.          | <i>P. ct.</i> | <i>P. ct.</i> | <i>P. ct.</i> | <i>P. ct.</i> | <i>P. ct.</i> | <i>P. ct.</i> | <i>P. ct.</i> | <i>P. ct.</i> | <i>P. ct.</i> | <i>P. ct.</i> | <i>P. ct.</i> | <i>P. ct.</i> |
| November.....  | 52            | (65)          | .....         | 25            | (19)          | .....         | 12            | (8)           | .....         | 11            | (8)           | .....         |
| December.....  | 71            | (58)          | 55            | 18            | (33)          | 34            | 3             | (4)           | 5             | 8             | (5)           | 6             |
| 1914.          |               |               |               |               |               |               |               |               |               |               |               |               |
| January.....   | 56            | 67            | 62            | 26            | 18            | 23            | 11            | 7             | 7             | 7             | 8             | 8             |
| February.....  | 70            | 63            | 71            | 18            | 24            | 21            | 5             | 6             | 3             | 7             | 7             | 5             |
| March.....     | 70            | 64            | 73            | 16            | 23            | 18            | 7             | 9             | 5             | 7             | 4             | 4             |
| April.....     | 66            | 55            | 60            | 18            | 31            | 21            | 7             | 7             | 12            | 9             | 7             | 7             |
| May.....       | 63            | 56            | 58            | 21            | 25            | 27            | 8             | 11            | 9             | 8             | 8             | 6             |
| May 1.....     | 65            | 44            | 52            | 20            | 32            | 28            | 6             | 13            | 11            | 9             | 11            | 9             |
| June.....      | 65            | 57            | 54            | 21            | 27            | 27            | 7             | 8             | 11            | 7             | 8             | 9             |
| July.....      | 64            | 57            | 57            | 19            | 25            | 25            | 9             | 10            | 9             | 8             | 8             | 9             |
| August.....    | 70            | 64            | 59            | 17            | 24            | 25            | 7             | 6             | 7             | 6             | 6             | 9             |
| September..... | 75            | 81            | 83            | 13            | 18            | 13            | 6             | 0             | 2             | 6             | 1             | 2             |
| October.....   | 82            | 90            | 82            | 8             | 9             | 15            | 3             | 0             | 3             | 7             | 1             | 0             |
| November.....  | (87)          | 88            | 82            | (7)           | 11            | 15            | (2)           | 1             | 2             | (4)           | 0             | 1             |
| December.....  | (87)          | 91            | (92)          | (8)           | 7             | (7)           | (2)           | 1             | (0)           | (3)           | 1             | (1)           |
| Average.....   | 68            | 68            | 67            | 18            | 21            | 22            | 6             | 6             | 6             | 8             | 5             | 5             |

TABLE 4b.—Percentage of mash feeds consumed each 4-week period (third year for Pens 3 and 4, second year for Pen 7).

| Period.        | Corn meal.    |               |               | Beef scrap.   |               |               | Bran.         |               |               | Middlings.    |               |               |
|----------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
|                | Pen 3.        | Pen 4.        | Pen 7.        | Pen 3.        | Pen 4.        | Pen 7.        | Pen 3.        | Pen 4.        | Pen 7.        | Pen 3.        | Pen 4.        | Pen 7.        |
| 1914.          | <i>P. ct.</i> | <i>P. ct.</i> | <i>P. ct.</i> | <i>P. ct.</i> | <i>P. ct.</i> | <i>P. ct.</i> | <i>P. ct.</i> | <i>P. ct.</i> | <i>P. ct.</i> | <i>P. ct.</i> | <i>P. ct.</i> | <i>P. ct.</i> |
| November.....  | 87            | (88)          | (82)          | 7             | (11)          | (15)          | 2             | (1)           | (2)           | 4             | (0)           | (1)           |
| December.....  | 87            | (91)          | 92            | 8             | (7)           | 7             | 2             | (1)           | 0             | 3             | (1)           | 1             |
| 1915.          |               |               |               |               |               |               |               |               |               |               |               |               |
| January.....   | 89            | 96            | 91            | 7             | 3             | 6             | 2             | 1             | 2             | 2             | 0             | 1             |
| February.....  | 92            | 94            | 90            | 5             | 5             | 4             | 1             | 0             | 3             | 2             | 1             | 3             |
| March.....     | 87            | 97            | 88            | 4             | 3             | 8             | 2             | 0             | 2             | 7             | 0             | 2             |
| April.....     | 82            | 87            | 88            | 6             | 6             | 9             | 6             | 3             | 2             | 6             | 4             | 1             |
| May.....       | 76            | 84            | 87            | 9             | 7             | 9             | 7             | 5             | 2             | 8             | 4             | 2             |
| May.....       | 79            | 81            | 85            | 7             | 10            | 10            | 6             | 5             | 4             | 8             | 4             | 1             |
| June.....      | 82            | 85            | 80            | 6             | 8             | 13            | 6             | 4             | 5             | 6             | 3             | 2             |
| July.....      | 80            | 89            | 85            | 9             | 5             | 12            | 5             | 4             | 2             | 6             | 2             | 1             |
| August.....    | 83            | 88            | 82            | 7             | 3             | 13            | 5             | 6             | 2             | 5             | 3             | 3             |
| September..... | 87            | 89            | 87            | 5             | 6             | 11            | 4             | 3             | 1             | 4             | 2             | 1             |
| October.....   | 74            | 97            | 85            | 14            | 3             | 11            | 4             | 0             | 3             | 8             | 0             | 1             |
| November.....  | 95            | 88            |               | 5             | 12            |               |               | 0             |               |               | 0             |               |
| December.....  | 96            |               |               | 3             |               |               |               | 0             |               |               | 1             |               |
| Average.....   | 84            | 91            | 86            | 7             | 5             | 10            | 4             | 2             | 2             | 5             | 2             | 2             |

TABLE 4c.—Average percentage of mash feeds consumed each year.

| Year.     | Pen. | Corn meal.       | Beef scrap.      | Bran.            | Middlings.       |
|-----------|------|------------------|------------------|------------------|------------------|
|           |      | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> |
| 1913..... | 3    | 63               | 19               | 9                | 9                |
| 1913..... | 4    | 63.7             | 27               | 4.9              | 4.4              |
| 1914..... | 3    | 68               | 18               | 6                | 8                |
| 1914..... | 4    | 68               | 21               | 6                | 5                |
| 1914..... | 7    | 67               | 22               | 6                | 5                |
| 1915..... | 3    | 84               | 7                | 4                | 5                |
| 1915..... | 4    | 91               | 5                | 2                | 2                |
| 1915..... | 7    | 86               | 10               | 2                | 2                |

All the records are based on 13 periods of 4 weeks each, into which each year is divided. This accounts for a repetition of May in these and other tables. The exact periods for the different pens were as follows:

Pens 1, 2, and 3: 1, November 1 to 28; 2, November 29 to December 26; 3, December 27 to January 23; 4, January 24 to February 20; 5, February 21 to March 20; 6, March 21 to April 17; 7, April 18 to May 15; 8, May 16 to June 12; 9, June 13 to July 10; 10, July 11 to August 7; 11, August 8 to September 4; 12, September 5 to October 2; 13, October 3 to October 31. The periods for Pens 4 and 5 begin January 18 and are as follows: 1, January 18 to February 14; 2, February 15 to March 14; 3, March 15 to April 11; 4, April 12 to May 9; 5, May 10 to June 6; 6, June 7 to July 4; 7, July 5 to August 1; 8, August 2 to August 29; 9, August 30 to September 26; 10, September 27 to October 24; 11, October 25 to November 21; 12, November 22 to December 19; 13, December 20 to January 17. Pen 6 began January 25 and continued as follows: 1, January 25 to February 21; 2, February 22 to March 21; 3, March 22 to April 18; 4, April 19 to May 16; 5, May 17 to June 13; 6, June 14 to July 11; 7, July 12 to August 8; 8, August 9 to September 5; 9, September 6 to October 3; 10, October 4 to October 31; 11, November 1 to November 28; 12, November 29 to December 26; 13, December 27 to January 24. Pens 7, 8, and 9 were entered in the experiment December, 1913, a year later than Pens 1 to 6, and their periods are as follows: 1, December 1 to December 28; 2, December 29 to January 25; 3, January 26 to February 22; 4, February 23 to March 22; 5, March 23 to April 19; 6, April 20 to May 17; 7, May 18 to June 14; 8, June 15 to July 12; 9, July 13 to August 9; 10, August 10 to September 6; 11, September 7 to October 4; 12, October 5 to November 1; 13, November 2 to November 30.





FIG. 1.—PEN 2, MIXED PEN OF GENERAL-PURPOSE BREEDS.

On free range; fed a ration without oats.



FIG. 2.—PEN 4, SINGLE-COMB WHITE LEGHORNS.

On free range; allowed to select their own mash.

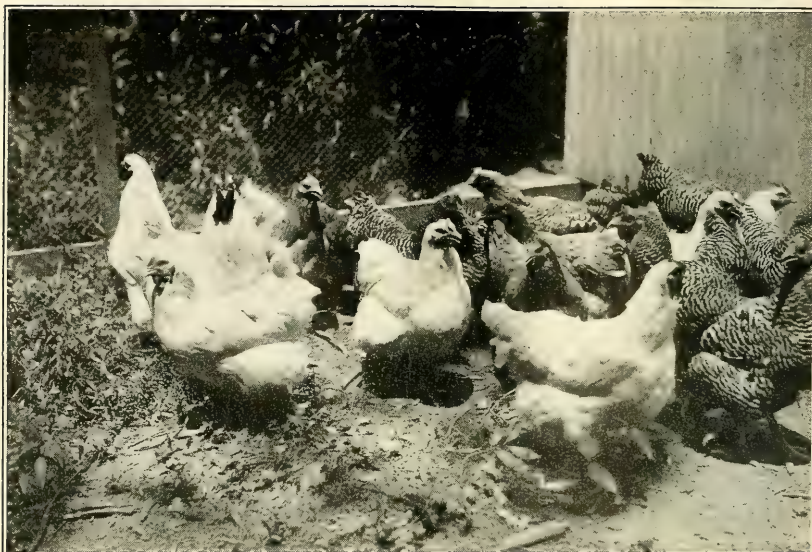


FIG. 1.—PEN 6, MIXED PEN OF GENERAL-PURPOSE BREEDS.

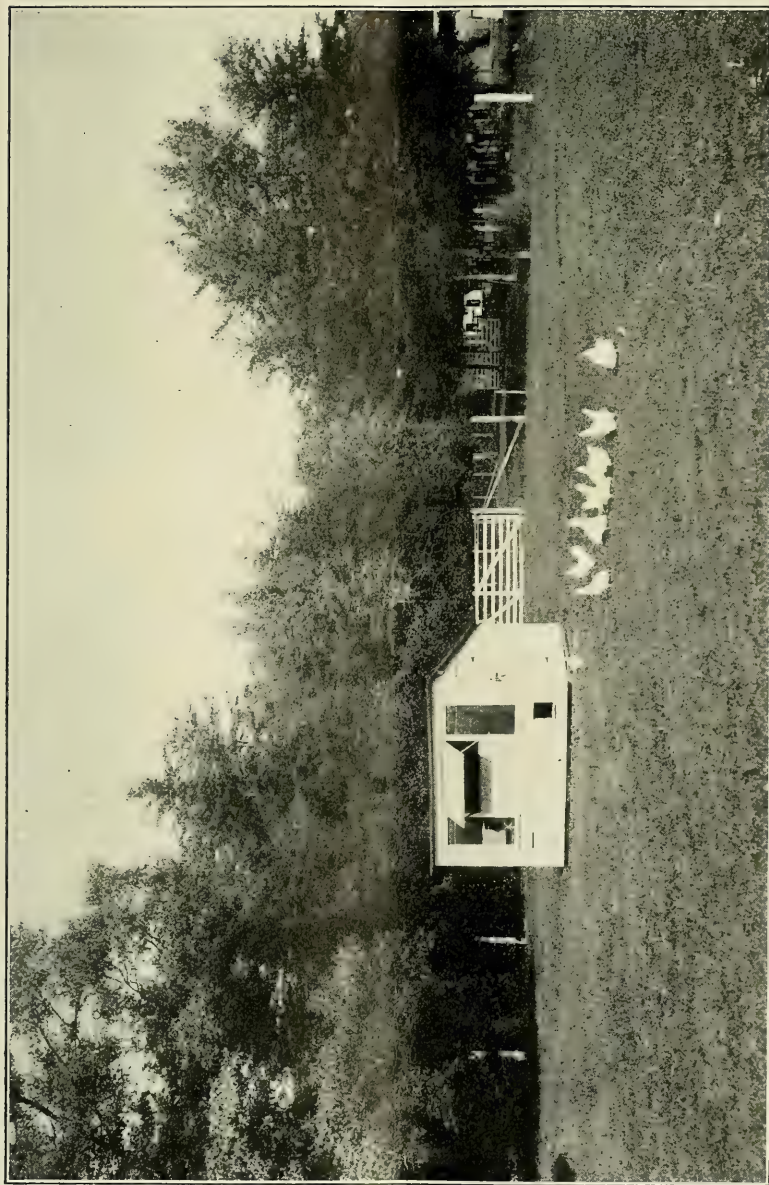
On free range; fed a scratch mixture containing barley, and had beef scrap separate from the mash.



FIG. 2.—PEN 7, WHITE LEGHORNS.

Confined to yard; allowed to select their own mash.





PEN 8, SINGLE-COMB WHITE LEGHORNS.

On free range; fed a mash containing two-thirds corn meal.



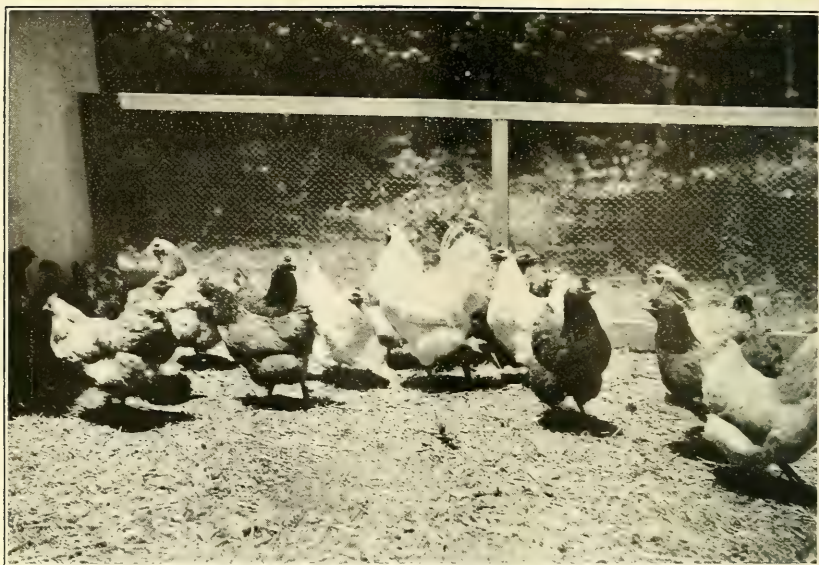


FIG. 1.—PEN 9, MIXED PEN OF GENERAL-PURPOSE BREEDS.  
On free range; not fed any beef scrap.

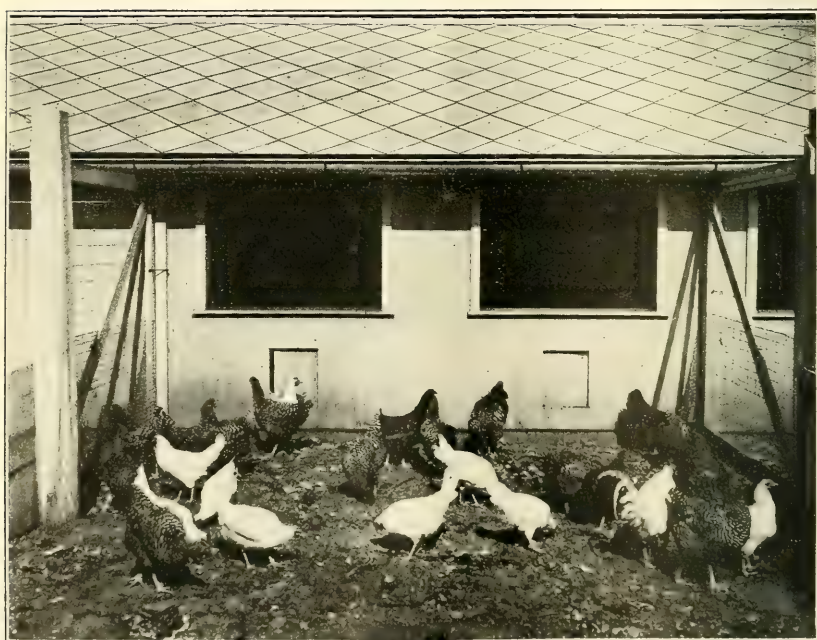


FIG. 2.—PEN 15, WHITE LEGHORNS AND BARRED PLYMOUTH ROCKS.  
On free range, fed one-third cottonseed meal in mash.

A study of Tables 4, 4a, 4b, and 4c, and the graphic representation in figure 2 shows a great variation in the proportions of the components of the mash consumed, especially in the corn meal and beef scrap. These percentages, if worked out on a weekly basis instead of for periods of four weeks, fail to show any constant relation between the percentage of either the corn meal or the beef scrap and the temperature or the egg production. The proportions of the grains seem to be influenced materially by the differences in years, or else by different lots of feed, especially beef scrap. This is shown in

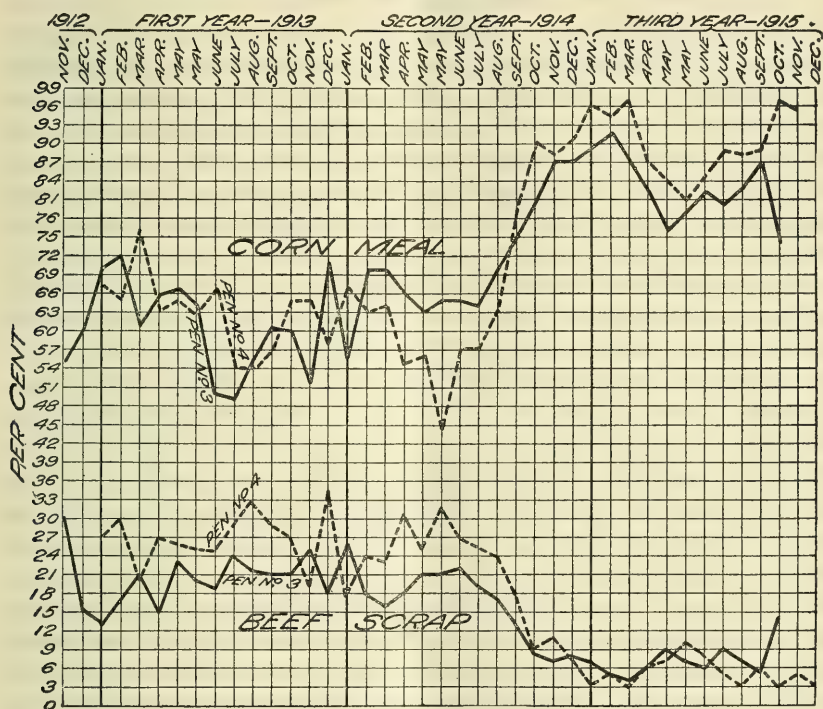


FIG. 2.—Hens balancing their own ration. Percentage of corn meal and beef scrap consumed in mash. (Bran and middlings were before the hens also, but only small quantities were consumed.)

the figure, where the curves for Pens 3 and 4 in 1913 are different from those in 1914, and the percentages in 1915 are very markedly different from those in either 1913 or 1914.

The tendency to increase the percentage of corn meal and decrease that of beef scrap during the molting period is very uniformly marked in 1914 but is not so apparent in 1913. This is rather contrary to the practice of increasing the percentage of protein during the molting period. The Leghorns ate a slightly larger proportion of beef scrap than did the general-purpose fowls, which difference was greater in 1913 than in 1914. The proportion of the grains eaten was

also influenced by the quality of the grains, as the fowls apparently liked some lots of feed better than others, although the quality and condition of all the grains were good. The average percentages for the different pens in both years are fairly uniform, as is shown in table 4c.

The results show that hens will not eat too much beef scrap and that they can be allowed to select their own mash feeds. One thing emphasized in this work is the large percentage of corn meal, which is 2 to 3 times as much as is usually recommended in a mash. The large percentage of corn meal in this mash did not tend to make the hens too fat, as shown by the monthly weight records in Table 10. The health of the fowls was in no way adversely affected by the large percentage of corn meal in the mash. Pen 3 went through its entire second year (1913-14) without any sickness or deaths and was the only pen in which no mortality occurred during that year. Pen 5, which also had a large percentage of corn meal in the mash, went through the year 1915, when they were 3-year-old hens, without any deaths.

The mash in Pen 5 was mixed according to the proportions eaten by Pen 3, as shown in Table 1. The mash originally contained 10 per cent bran, 12 per cent middlings, 63 per cent corn meal, and 15 per cent beef scrap, based on what Pen 3 was eating at that time. This was changed after Pen 3 had been in the experiment one year, using the average proportions for the year. Pen 5 laid as well as Pen 3 the first year, considering the difference in the time that the pens were started; and laid 22 more eggs per hen in 1914, producing eggs 2.5 cents per dozen cheaper. In 1915, Pen 5 laid 23 more eggs per hen than Pen 3 and produced eggs 2.3 cents per dozen cheaper. This difference in production during the second and third years is partly, if not entirely, due to the difference in time of year when these pens matured and started to lay. This is discussed more in detail on page 20. Pen 5 also received 12 per cent more beef scrap in 1915 than Pen 3, which tends to account for part of the increased production in the former pen. Pen 5 contained more broody hens in both 1913 and 1914 and the same number in 1915 as Pen 3.

The mash in Pen 8 was mixed according to the proportions eaten by Pen 4. Pen 8 laid 36.7 more eggs per hen than Pen 7 and produced eggs 2 cents per dozen cheaper in 1914, while in 1915 Pen 8 laid 44.8 more eggs per hen and produced eggs 1.9 cents per dozen cheaper than Pen 7. Pens 7 and 8 were started at the same time, but Pen 7 and Pen 4 were allowed to balance their own rations. Pen 7 was confined to a yard while Pens 4 and 8 were on free range. The effect of free range on egg production is discussed on page 16. Pen 8 received about 4 per cent more beef scrap than Pen 7 in 1914 and about 16 per cent more in 1915 and produced the highest



average egg yield (158) up to that time in these feeding experiments. This increased percentage of beef scrap in 1915 undoubtedly accounts partly for the increased production in Pen 8. The conclusion to be drawn from Pens 5 and 8, in which the mash was mixed as selected by the hens in Pens 3, 4, and 7, is that just as good results if not better are secured where a fixed mash is used throughout the year as where each mash constituent is fed separately.

### FEEDING VALUE OF POULTRY FEEDS.

#### THE VALUE OF OATS.

Pens 1 and 2 were fed alike (see Table 1) except that the oats were left out of the scratch ration in Pen 2. The egg yield was about the same in these pens the first year, but Pen 2 ate considerably less feed. Both pens were on free range. Pen 1 laid about 15 more eggs per hen than Pen 2 during their second year, but the feed cost of egg production was about the same (see Table 2). In their third year Pen 1 laid 12 more eggs per hen than Pen 2 and produced eggs 4 cents per dozen cheaper. The average cost of the eggs for three years is slightly in favor of Pen 1, but this difference is less than 1 cent per dozen and may not be entirely due to the difference in rations. The mortality in Pen 1 during the second year, although considerably greater than in Pen 2, was apparently due to the difference in the fowls and not to the feed.

Leaving the oats out of the scratch mixture in Pen 2 increased the cost of the mixture 6 cents per 100 pounds. The hens in Pen 2 tended to get overfat, which may be partly due to the larger proportion of corn in the scratch mixture, but was also affected by the breed of fowls, as discussed on page 36. With the mixture containing oats cheaper than one without this grain, there does not appear to be any reason for leaving it out of the ration, and the oats add variety to the feed. If the cost of a pound of oats should increase out of proportion to corn and wheat, a ration without oats would give good results.

#### THE VALUE OF BEEF SCRAP OR ANIMAL PROTEIN.

Pen 9 was fed a ration without beef scrap (see Table 1) to determine what results would be secured from fowls kept on free range and fed a standard ration with the animal protein (beef scrap) left out and not replaced by vegetable protein. This pen had an unlimited range in woods containing a brook which supplied bugs and is perhaps in many ways directly comparable to conditions on general farms, where beef scrap or any other material furnishing animal protein is not generally fed.

The fowls in this pen were in good breeding condition, or slightly thin, throughout the experiment, as opposed to the slight tendency to become overfat noted in nearly all other pens of general-purpose

fowls. The monthly average weight of the hens in this pen was 5.03 pounds, compared to 5.82 pounds in the other general-purpose pens during their first year, and 5.58 pounds, compared with 6.26 for these pens during their second year (see Table 10). These fowls were always hungry and busy scratching, wandering a considerable distance from their house to scratch in the leaves and on the banks of the brook.

Feather eating developed in this pen and the fowls picked the feathers from the neck of the male. This vice was apparently stopped by keeping salt pork before the birds until the male's neck was healed and covered with new feathers. A slight tendency toward this habit was noted in this pen throughout the year, but was not serious enough to warrant preventive measures except during the month of October, 1914. Feather picking did not develop in any of the other feeding pens, showing that the use of a good ration containing beef scrap practically prevents this vice among fowls kept under ordinary conditions.

The average feed consumed per hen in Pen 9 (see Table 2) was 61 pounds, which cost 88 cents, against an average consumption of 69 pounds which cost \$1.09, for Pens 1, 2, and 3 in 1913. The amount of feed increased to 74 pounds during the second year and cost \$1.10, compared with 65 pounds in Pens 1, 2, and 3, which cost \$1.02. The average feed cost of a dozen eggs in Pen 9 during the first year was 11.7 cents against 9.51 cents in Pens 1, 2, and 3 (1913), and it was 15.3 cents the second year against 15 cents for Pens 1, 2, and 3. It took 8.2 pounds of feed to make a dozen eggs in Pen 9 the first year against 6.04 pounds in Pens 1, 2, and 3, and 10.7 against 9.6 pounds the second year.

The average egg yield in Pen 9 was 90 eggs compared with 137.6 eggs for Pens 1, 2, and 3 during 1913, and 84.3 against 83 in the second year. The 2-year average annual production in Pen 9 was 87.1 eggs against 110.2 eggs in the beef-scrap pens. The 2-year average cost of a dozen eggs was 13.5 cents in Pen 9 against 12.2 in Pens 1, 2, and 3. Pen 9 did not lay well during the winter and practically stopped laying whenever the ground was covered with snow (see Table 6). This affected the value of the eggs materially. Pen 9 was started December 1, while Pens 1, 2, and 3 were put into the experiments November 1, so that the difference in results between these pens is somewhat greater than it would have been if all the pens had started to lay in the same month.

The average weight of a dozen eggs for the first year in Pen 9 was 1.50 pounds against an average of 1.56 pounds for Pens 1, 2, and 3, and 1.56 against 1.62 during the second year. The mortality in Pen 9 was 2 hens compared with an average of 4.3 in Pens 1 to 6 during the first year, but was 4 dead from natural causes in the second year,

and 2 killed by the other hens picking and eating their flesh, against 3.3 dead from natural causes in the other pens. The picking was due to the lack of beef scrap or other animal-protein feed. It would not appear that the beef scrap affected the mortality from natural causes in these experiments. No tests were made of the eggs from this pen used for hatching, but of the eggs hatched no differences in fertility or hatchability were noted between this pen and those fed beef scrap.

A study of the results shows that beef scrap or some other animal protein, even with fowls on a good range, was an economical feed and that its use materially increased egg production and the market value of the eggs. This is especially true during the first year's production, which was very materially stimulated by the beef scrap; the second year's results were about equal in the beef scrap and no beef scrap pens. The difference in egg yield would probably be greater with fowls confined to yards. Beef scrap and fish meal appear to be the only feeds in these rations which very materially affect the egg yield. The variation in the proportions of the other feeds, or even the omission of any one of them, does not appear to affect the egg yield as greatly as do these feeds.

#### COTTONSEED MEAL.

Cottonseed meal is more readily available and is cheaper, especially in the South, than beef scrap. This meal has a high protein content, and if it would give as efficient results considering its relative protein content, it would be a more economical feed than beef scrap. Pens 10 and 11 were started in November, 1914, on rations containing cottonseed meal. Their mash (see Table 1) was composed of about one-third cottonseed meal, and the protein content equaled that of Pen 12, which was fed beef scrap in place of cottonseed meal and used as a check pen. A small amount (about 3.5 per cent) of beef scrap was included in the mash in Pen 11 to see if this amount would supply the mineral matter which might be lacking in the cottonseed meal and make the use of the meal more efficient. The total cottonseed meal in the entire ration of Pens 10 and 11 was about 13 per cent, and about 15 per cent in Pen 15. Pens 15 and 16 were started in March, 1915, on rations similar to those used in Pens 10 and 11, respectively. The method of feeding was similar to that used in the other pens except that it was practically impossible to get the hens fed cottonseed meal to eat enough mash so that half mash and half scratch grains could be fed. The hens were always hungry and were very thin, so that it seemed advisable to feed a larger proportion of scratch grains. The average weights of these hens, as shown in Table 10, were very low, Pens 10 and 11 averaging throughout the year a pound less per hen than Pen 12.



The weights of the hens in all of the cottonseed pens were far below those of hens of the same breeds in beef-scrap pens.

These pens were all on free range and thus were able to secure considerable feed from the range. Several times during the year the hens in Pens 10, 11, and 16 were found to be going to other feeding pens and eating their mash. Their ration apparently was deficient in some desired element, so that they would go long distances to secure other feed. This mixing at least partly accounts for the variable results secured in these pens.

The results with the cottonseed meal, as shown in Table 2, first year, pens 10 to 16, were not satisfactory. Pen 12, fed beef scrap, laid about 66.5 more eggs per hen, produced eggs 2.4 cents per dozen cheaper, and gave a profit over feed cost \$1.68 per hen greater than in Pens 10 and 11. The results in Pens 15 and 16 were even more decisive against the use of cottonseed meal as an economical feed, Pen 15 averaging only 33.2 eggs per hen during the year and showing a net loss over feed cost alone of 4 cents per hen for the year. The feed cost of eggs in this pen was 31.9 cents per dozen. The hens fed cottonseed meal also failed to lay many eggs during the winter, and those produced in two of these pens (Nos. 15 and 16) were small (see weight of eggs in Table 5b).

In addition to proving an uneconomical feed, the cottonseed meal affected the appearance and firmness of the eggs, making a considerable percentage of them unmarketable. (See Pl. VII.) Dark-greenish spots of varying sizes were produced on the yolks of the eggs, while the contents in most cases lacked firmness and they would not poach like eggs produced from beef-scrap rations. During warm weather about half of these eggs were classed as unfit for food as judged by appearance, although no disagreeable effects were noted from eating eggs discolored in this manner. During cool and cold weather the quality of these eggs was considerably better than in warm weather.

Comparing the cottonseed pens (Nos. 10 and 15) with those fed about 3.5 per cent of beef scrap in the mash in addition to the cottonseed meal (Nos. 11 and 16), the results were inconsistent, owing at least partly to the fowls mixing. The egg yield in Pens 10 and 11 was about the same, but Pen 16, fed this small amount of beef scrap, laid twice as many eggs as Pen 15, which was without any beef scrap. No material difference was noted in the quality of the eggs from any of the pens. The egg yield and quality of eggs in all these pens were unsatisfactory, and cottonseed meal, either with or without a very small percentage of beef scrap, is not an economical feed for poultry. It is possible that a part (perhaps half) of the beef scrap could be replaced by cottonseed meal to better advantage.

## FISH MEAL.

Fish meal, a by-product of the menhaden industry, was used to replace beef scrap in the ration of Pen 13, in comparison with Pen 14, a check pen receiving beef scrap. The mash in Pen 13 contained 20 per cent fish meal, while that of Pen 14 contained the same percentage of beef scrap. (See Table 1.) The fish meal was given an estimated value of \$46 per ton, at which price (\$7 per ton cheaper than beef scrap) the fish meal proved a good substitute for beef scrap and an economical feed. The protein in the fish meal appeared to be as efficient as that in the beef scrap, considering the relative composition of the feeds.

No abnormal effects were noted in the size, taste, or quality of the eggs from the pen fed fish meal. The fowls in both pens kept in good condition and the mortality was low. Both pens were on free range, but the range of the fish-meal pen was largely in grass while the beef-scrap pen ranged in the woods where there was not any greensward. This difference in range would be slightly in favor of the fish-meal pen. This experiment did not begin until the middle of January, and the egg production in both of these pens was very good for pullets started at that time of the year. Each pen contained 18 pullets.

The egg yield per hen on beef scrap was 160, compared with 145.4 on fish meal, but the latter pen produced eggs at 8.5 cents per dozen, while the eggs from the former pen (beef scrap) cost 9.7 cents. The profit per hen over feed cost was about equal, being 7 cents greater in the beef-scrap pen (see Table 2). The beef scrap was about 6 per cent higher in digestible crude protein than the fish meal (see Table 12), so about one-tenth more fish meal than beef scrap might be fed to advantage in the mash to make the protein content equal. Both fish meal and fish scrap may also be fed with beef scrap with excellent results, replacing about half of the beef scrap with the fish product.

## VALUE OF GROUND GRAINS.

Pen 6 was started on a ration (see Table 1) of scratch grains, with beef scrap before the hens all the time. No dry mash of ground grains was fed; the object being to compare the effect and value of the mash in the ration. The hens ate the beef scrap freely, but constant diarrhea developed in the pen, so that it appeared advisable to keep a mixture of equal parts of corn meal and middlings before the hens, which largely checked this evil. The birds were given all the scratch grains they would clean up and ate 16 per cent of mash in 1913, 26 per cent in 1914, and 27 per cent in 1915. The percentage of beef scrap in the total ration in this pen beginning in January, for 4-week periods, was as follows: In 1913: 14, 13, 8, 16, 11, 4, 4, 2, 2,

4, 11, 6, and 6. In 1914: 10, 10, 10, 8, 8, 11, 8, 6, 8, 6, 2, 4, and 8. In 1915: 6, 4, 5, 3, 7, 4, 4, 5, 4, 3, 7, 7, and 5. Barley was fed in this grain mixture (see Table 1).

Pens 5 and 6 were started in January at about the same time and their egg yields the first year were practically equal, but the hens in Pen 6 consumed 6 pounds more of feed per hen, at an additional cost of 17 cents, while it took 0.76 pounds more of feed to produce a dozen eggs, costing 1.94 cents more per dozen. The hens in Pen 6 during their second year ate 10 pounds more of feed than those in Pen 5, costing 17 cents more per hen, while it took 2 pounds more of feed to produce a dozen eggs, costing 3.4 cents more per dozen. In the third year these two pens produced about the same number of eggs, but Pen 5 ate 14 pounds less of grain per hen. Pen 5 produced eggs 2.8 cents per dozen cheaper that year than Pen 6, and the profit per hen over feed cost was 24 cents greater. Pen 6 had the advantage of being on free range, while Pen 5 was confined to yards, and the latter pen contained a much larger number of broody hens than Pen 6. This ration and method of feeding kept the hens too fat (Pen 6), as shown in Table 10. The hens ate the barley freely, and this grain appears to be a good feed to use if cheaper than wheat or to add variety to the ration. However, the comparative value of barley and wheat is not in any way determined by this experiment.

This ration and method of feeding appears to be less desirable than any other in which beef scrap was used. The hens in Pen 6 ate more grain than any other pen, had the highest feed cost, produced eggs at the greatest cost per dozen compared with the other pens started at the same time, and were overfat. Regulating the proportions of mash and scratch grains to about equal parts of each keeps the fowls in better condition than where only a small proportion of mash is fed. Mortality does not appear to be materially influenced by the relative proportions of scratch grains and mash in the ration, if the percentage of beef scrap is not materially changed. A ration including a mash containing beef scrap, or with the beef scrap fed separately, makes a cheaper and better ration than one without the mash, even though the beef scrap is supplied.

#### FREE RANGE COMPARED WITH LARGE YARDS.

All pens except Nos. 3, 5, and 7 had free range, while these pens were confined to large yards (see Table 1). However, other changes besides the range enter into a comparison of these pens with the range pens, making it hard to draw definite conclusions, but the evidence points strongly to better egg yield and other results on free range, especially with Leghorns. The greatest difference due perhaps to free range is noted in Pen 8, in which during their first year 36 more eggs per hen were laid than in Pen 7, while in their second year the



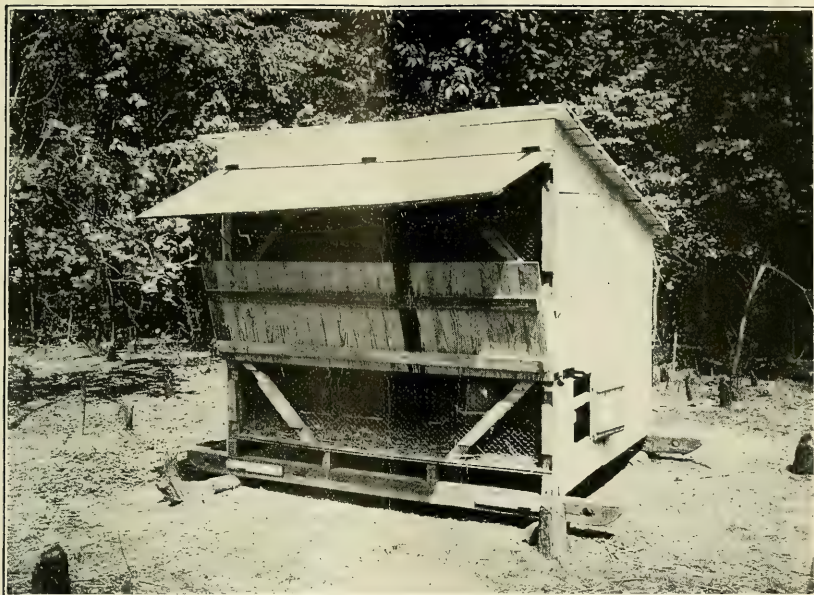


FIG. 1.—COLONY GROWING HOUSE USED AT GOVERNMENT POULTRY FARM, BELTSVILLE, MD.

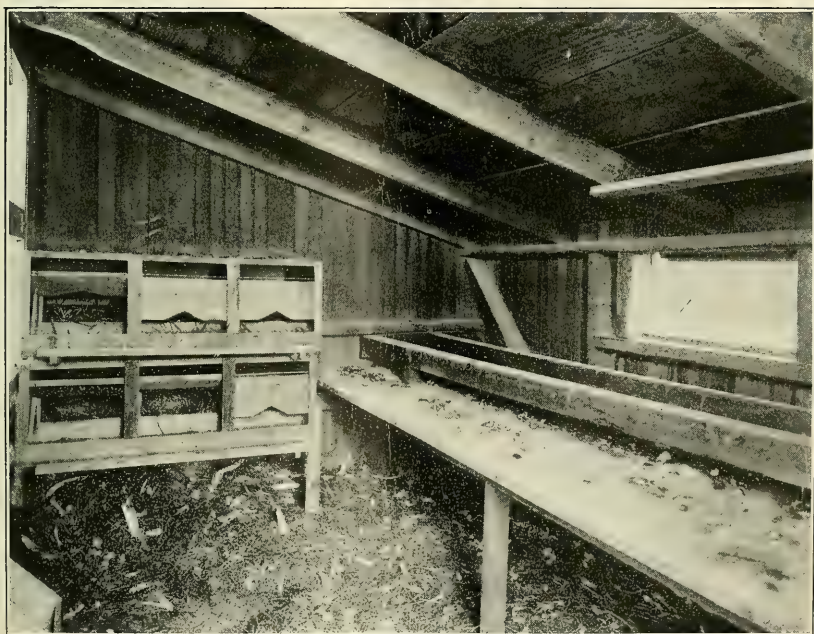


FIG. 2.—INTERIOR OF COLONY HOUSE SHOWN IN PLATE III.  
Showing litter on floor, dropping boards, roosts, and nests.

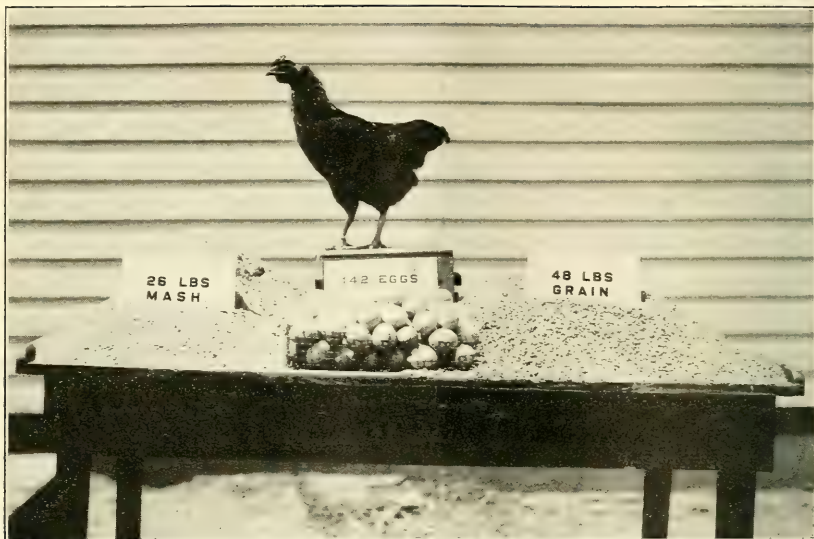


FIG. 1.—AVERAGE RESULTS IN PEN 1 (RHODE ISLAND REDS) DURING PULLET YEAR.

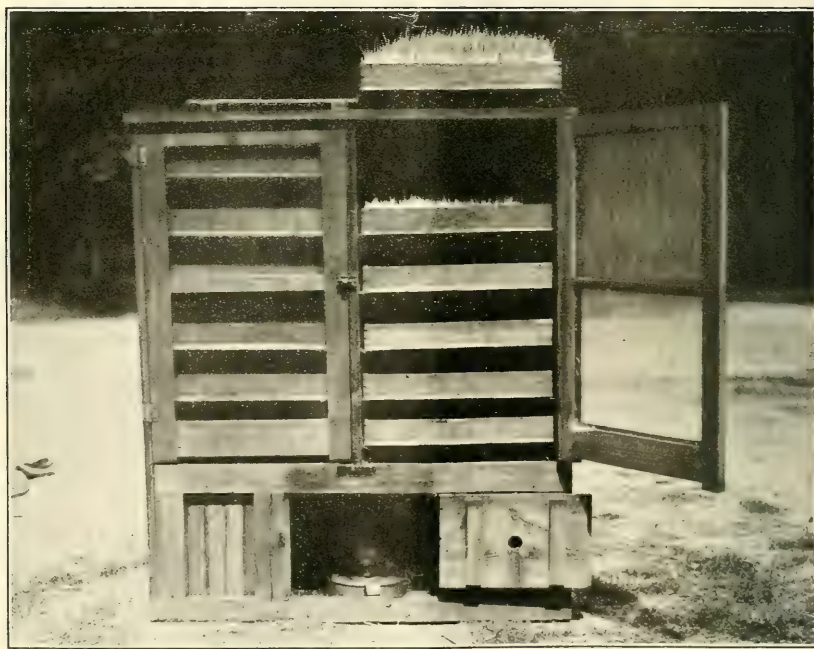


FIG. 2.—OATS SPROUTER. ONE TRAY OF OATS ON TOP OF CASE READY TO BE FED.

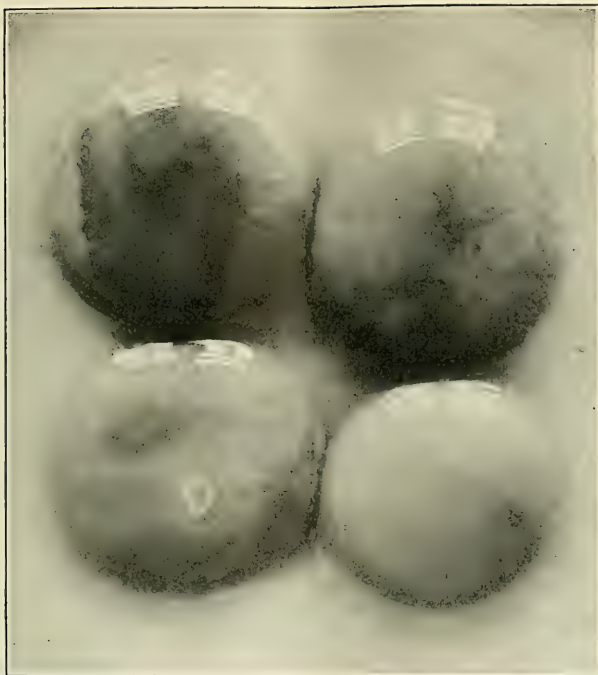


FIG. 1.—EGGS FROM PEN 15, SHOWING EFFECT OF SMALL PERCENTAGE OF COTTONSEED MEAL IN RATION.

Normal egg in lower left-hand corner.

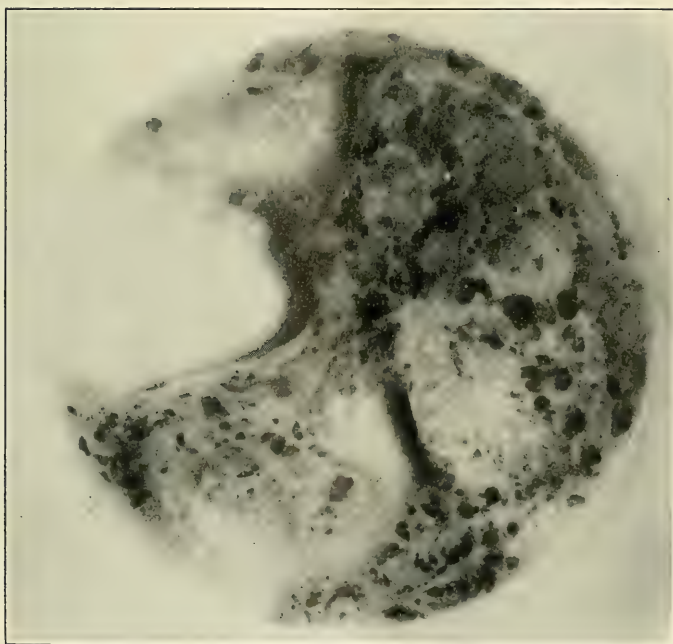


FIG. 2.—EGG SIMILAR TO THOSE IN UPPER PICTURE, WITH YOLK BROKEN OPEN.



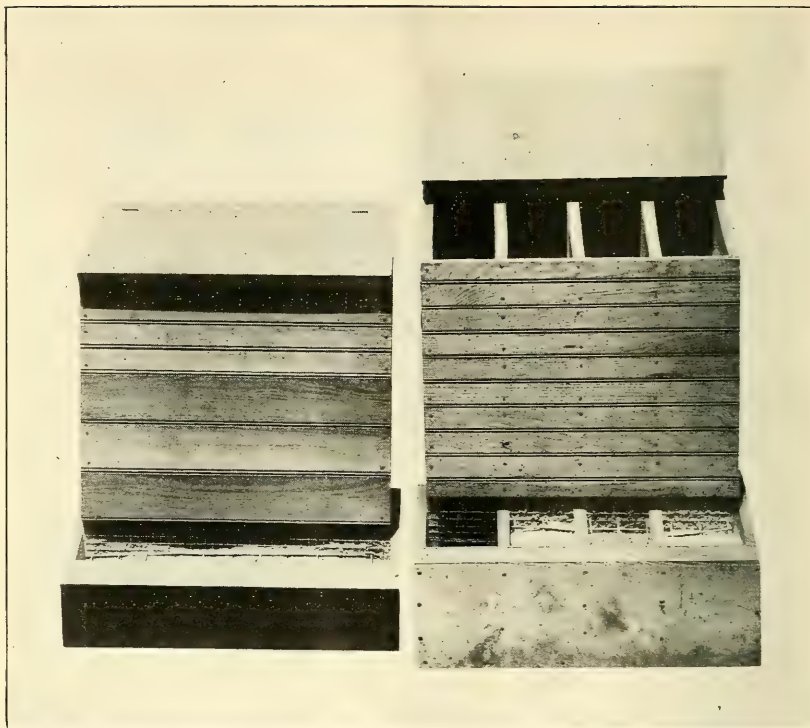


FIG. 1.—DRY-MASH HOPPERS.

The hopper on the right has separate compartments, and was used in pens 3, 4, and 7.

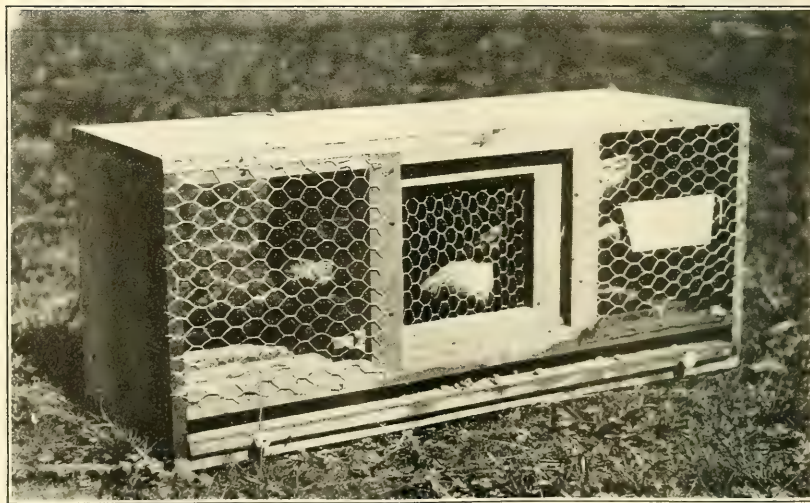


FIG. 2.—COOP FOR BROODY HENS.

This coop is hooked to the inside wall of the house, above the nests.

difference was 45 eggs per hen in favor of free range. These two pens of Leghorns are apparently fairly comparable, as they are of similar breeding, they were reared under similar conditions, were started at the same time, and received almost similar rations except that in Pen 7 the mash constituents were separate while they were mixed together in Pen 8. This difference in the method of feeding, as previously discussed, does not appear to be a material factor in affecting the egg yield. Pen 8, however, received 4 per cent more beef scrap than Pen 7 in 1914, and 16 per cent more in 1915, which is a very material factor. A comparison of Pen 4, which was on free range, with Pen 7 (confined) appears to strengthen the conclusion that free range materially increases egg yield, as the percentage of beef scrap consumed in these pens was more nearly equal. The Leghorns ranged over a wide area, while the general-purpose breeds neither kept as busy scratching nor ranged over nearly as much ground.

The use of yards does not appear to affect the mortality among the fowls for a period of one or two years (see Table 2). The loss in the confined pens was in several instances considerably less than in the pens on free range, but part of the additional loss on free range was caused by hawks and missing fowls. The greatest mortality occurred in the pens giving the highest egg production, and it would appear that this difference in egg production, rather than free range, was the material factor in causing the difference in mortality in Pens 7 and 8. It would not appear that free range of itself, except for the loss caused by hawks or other marauders, increased the mortality. Free range did not lower the total consumption of grain nor decrease the cost of feeding, except for the green feed which was supplied to the pens confined to yards. On the whole the consumption of grain was greater with the pens on range, owing to the greater production in these pens. The cost of the dry oats used for green feed (sprouted oats) per hen averaged about 10 cents per year. A study of all these pens appears to show that free range very materially increases the egg yield in Leghorns, and somewhat, but to a considerably less extent, in the general-purpose breeds.

#### YARDS AND GREEN FEED.

Pens 3 and 5 each had a large yard containing about 220 square feet of land per fowl and were kept in this yard about one year. They were then moved to a similar yard and the old yard was plowed and planted to grass, clover, and oats. The present plan is to alternate these yards once yearly, plowing and seeding the ground not in use, and thus keep the soil sweet as well as to provide some green feed. The soil in these yards is a heavy clay, parts of which are poorly drained and not well adapted for a permanent greensward. The yards contained only a small amount of grass and weeds when the

fowls were first put into them. Two yards for each pen allows about 440 square feet of ground per fowl, which is at the rate of about 100 hens to the acre. Pen 7 was confined to a single yard, which was plowed and planted after the hens had been in the yard about 9 months. The hens were confined by a temporary fence to a space of about one-tenth of the entire yard for 4 weeks until the oats were well started. This pen has a yard space of 218 square feet per hen, or about 200 hens to an acre. A single yard handled in this manner does not provide a good yarding system for poultry on heavy clay land. The growing grain and grass is all killed within a few weeks, and the yard is entirely bare the rest of the year.

No green feed was supplied to the pens on free range, but sprouted oats were fed at noon daily to those confined to yards (Pens 3, 5, and 7). Pens 3 and 5 were fed some cabbages during their first winter (1912 to 1913), but did not receive green feed regularly until March, 1913, when the sprouted oats secured from half a pound of dry oats were fed daily. The amount of dry oats per pen was increased at the beginning of 1914 to 0.6 of a pound (about 1½ square inches of sprouted oats daily per hen) and fed to Pens 3, 5, and 7. The cost of green feed in 1912 to 1913 per dozen eggs in Pens 3 and 5 was 0.8 and 0.9 cents, respectively. The cost per hen was 8.7 cents in Pen 3 and 9 cents in Pen 5. The cost of the green feed includes only the cost of the cabbages used in 1912 and 1913 and the cost of the dry oats for the rest of the time. In 1913 and 1914 the cost per dozen eggs in Pens 3, 5, and 7 was 1.8, 1.5, and 1 cents, respectively, and the cost per hen was 11.4 cents in Pen 3, 11.7 cents in Pen 5, and 10 cents in Pen 7. This cost was proportionately greater in 1915, as the same quantity of oats was fed to each pen, while the number of hens had decreased slightly, and the egg yield had decreased materially. Thus the green feed increased the cost of feeding the hens about 10 cents each, and during their first two years added a little over 1 cent per dozen to the cost of the eggs.

#### CONSUMPTION OF GRIT AND OYSTER SHELL.

The hens in 1912 to 1913 were fed about 1.3 pounds each of grit and oyster shell, which cost about 1.6 cents per hen. In 1913 to 1914 the hens were fed about the same amount of oyster shell but only about one-third as much grit, reducing the cost to about 1 cent per hen. During the third laying year, as egg production decreased the hens consumed considerably less grit and oyster shell. The consumption was slightly greater in Pens 9 and 10, where no beef scrap was fed, than in the beef-scrap pens. Pens 10 to 16 ate on the average in one year from 0.5 to 1 pound of grit per hen and from 1.5 to 2.5 pounds of oyster shell.



**LEGHORNS COMPARED WITH GENERAL-PURPOSE BREEDS.**

Leghorns produce eggs cheaper than hens of the general-purpose breeds (Plymouth Rocks, Wyandottes, Rhode Island Reds, and Orpingtons), because they lay as many or more eggs, eat only about 55 pounds of feed per head annually compared with from 70 to 85 pounds eaten by general-purpose breeds, and their egg yield very materially exceeds that of the general-purpose breeds during their second and third laying years (see Table 2). The feed cost of a dozen eggs for Pen 4 (Leghorns) was 7.34 cents in 1913, while the average cost of all the general-purpose breeds was 10.6 cents. In 1914 the feed cost of a dozen eggs for Pen 4 was 8.7 cents as against an average cost of 15.1 cents for the second laying year of the general-purpose pens. During their third laying year the cost of a dozen eggs was 8.8 cents for the Leghorns compared with 18.6 cents for the general-purpose fowls (Pens 5 and 6). The total profit per hen over feed cost in Pen 4 (Leghorns) for three years was \$6.84 against \$4.30 for Pens 5 and 6 (general-purpose fowls). Pen 8 (Leghorns) in 1914 laid 157.6 eggs per hen, the highest egg production secured in any of the feeding experiments up to 1915, producing eggs at a feed cost of 6.7 cents a dozen. Pen 12 composed of general-purpose fowls and crosses containing some Leghorn blood, laid 169.5 eggs per hen in 1915. The amount of grain eaten was large, however, making the feed cost of a dozen eggs 10.2 cents. The cost in Pen 2 during its first year was 7.74 cents, which was the lowest cost of any of the general-purpose pens. The average cost of eggs in Pens 7 and 8 (Leghorns) in 1914 (their first year) was 7.7 cents. For the first two years the average annual feed cost for Leghorns was about 88 cents and for the general-purpose breeds \$1.13.

The Leghorns produced smaller eggs than the general-purpose breeds. The average weight of the eggs in Pen 4 (Leghorns) during the first laying year weighed 1.42 pounds per dozen, as against 1.53 to 1.58 pounds for the other pens. (See Table 5.) However, Leghorns laying eggs weighing 1.50 pounds per dozen or over have been selected and bred by many poultrymen. An examination of 500 eggs from the Leghorn pens (Nos. 4, 7, and 8) made the first of May, 1915, showed that 31 per cent weighed over 2 ounces apiece, or 1.5 pounds to the dozen. The percentages and weights of these eggs were as follows: Eight per cent under  $1\frac{3}{4}$  ounces, 26 per cent from  $1\frac{3}{4}$  up to (not including)  $1\frac{7}{8}$  ounce, 35 per cent from  $1\frac{7}{8}$  to 2 ounces, 23 per cent from 2 to  $2\frac{1}{8}$  ounces, and 8 per cent over  $2\frac{1}{8}$  ounces.

The Leghorns in Pen 4 increased less than one-half pound in weight from the beginning of the experiment, January, 1913, until January, 1915, while the general-purpose breeds (Pens 5 and 6) increased a little over a pound during the same period. (See Table 10.) The

Leghorns increased about one-fifth of a pound in weight during their third year while the general-purpose pens increased one-third of a pound. In comparing the market value of the fowls this extra weight should be credited to the general-purpose fowls. The Leghorns do not tend to become overfat during their second and third laying years as do most of the general-purpose breeds.

The value per dozen of the eggs produced by the Leghorns (Pens 4, 7, and 8) was from 1 to 3 cents less each year than that of the general-purpose pens. (See Table 9.) This difference in value is due to the fact that the general-purpose breeds are better winter layers than the Leghorns, while the latter give a higher production in the spring and summer. This difference is more marked in the second than in the first or third years, as shown in Table 6, where Pens 7 and 8 (Leghorns) laid nearly as well during their first winter as the general-purpose pens (Nos. 1, 2 and 3), although the average value of the eggs per dozen for the year was slightly less in the Leghorn pens. Very few Leghorns become broody, which probably materially affects their egg yield as compared with the general-purpose breeds (see page 35). Better fertility in the eggs, especially with stock confined to yards, is more often secured from Leghorns than from the general-purpose or from any of the heavier breeds. No experiments have been conducted on the fertility and hatchability of the eggs from any of these feeding pens, but eggs have been hatched from several of them and no marked differences due to the feeding or method of management have been noted. Summing up these comparisons, the Leghorns are undoubtedly more profitable fowls to keep for the production of eggs only than are the general-purpose breeds, which confirms the belief and experience of commercial poultry farmers producing eggs for market.

#### EGG YIELD AS AFFECTED BY TIME OF MATURITY AND AGE OF FOWLS.

The average decrease in egg production of all the general-purpose breeds during their second year was 42.4 eggs, or about 32 per cent, while the decrease in the Leghorns (Pen 4) was only 21.9 eggs, or about 16 per cent. The decrease in all general-purpose pens from the second to third year production was about 16 per cent. The decrease in Pen 4 (Leghorns) was only 4 per cent. However, the decrease in Pens 5 and 6, which were started at the same time as Pen 4, was only 20 per cent during their second year and 13 per cent during their third year, as discussed later in this paragraph. The time of maturity affects this question materially, as the fowls which began to lay in November (Pens 1, 2, and 3) laid 17.8 more eggs per hen during their first year than Pens 5 and 6, which began to lay in January. On the other hand, Pens 1, 2, and 3 (early matur-

ing) laid 40 per cent less their second than during their first year, while Pens 5 and 6 (late maturing) laid only 20 per cent less. During their third year the egg production decreased 20 per cent in the early-maturing against 13 per cent in the late maturing pens. The fowls in this experiment, which matured late laid later in the season in both their first and second laying years, and while the value of their eggs was less the first year than that of the early maturing fowls, it was greater in their second year, largely because they laid a larger percentage of their eggs later in the season when the value per dozen is greater. The average yearly egg production (110.2 eggs) for two years of the general-purpose pens (Nos. 1, 2, and 3), which started to lay in November exceeds the average yearly production (107.7) of Pens 5 and 6 by only 2.5 eggs. (See Table 2.) The average three-year production for the early maturing pens (Nos. 1, 2, and 3) was 94.7 eggs against 99.5 in the late maturing pens (Nos. 5 and 6).

The average yearly value per hen of the eggs in Pens 1, 2, and 3, for two years was \$3.06 against \$2.97 in Pens 5 and 6; for three years the averages were \$2.55 and \$2.69, respectively. In other words, the value of the eggs for two years from the hens which started to lay early slightly exceeded the value of those which started to lay late, while for three years the value of eggs from the late-hatched pens exceeded that of the early hatched pens by 14 cents per hen. Comparing the yearly average for two years of Pen 4 (Leghorns) with Pens 5 and 6 (general purpose) all of which were late-maturing pens, the former averaged 126.8 while the latter averaged 107.7, or 19.1 eggs less. For three years the Leghorns averaged 121.9 eggs against 99.5 eggs in Pens 5 and 6. The yearly average value for two years of the eggs from Pen 4 was \$3.25 against \$2.92 from Pens 5 and 6. The average for three years was \$3.09 in Pen 4 against \$2.65 in Pens 5 and 6. The yearly average yield of all the general-purpose breeds was 109.3 eggs for two years and 71.4 for three years.

#### WEIGHT OF EGGS.

The average weight of eggs during each 4-week period throughout the year is shown in Tables 5, 5a, and 5b, with the pens arranged so that the dates of the periods correspond as nearly as possible.



TABLE 5.—*Weight of eggs per dozen, by 4-week periods, 1912-13.*

| Period.        | First laying year. |                |                |                |                |                |
|----------------|--------------------|----------------|----------------|----------------|----------------|----------------|
|                | Pen 1.             | Pen 2.         | Pen 3.         | Pen 4.         | Pen 5.         | Pen 6.         |
| 1912.          | <i>Pounds.</i>     | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> |
| November.....  | 1.52               | 1.47           | 1.46           |                |                |                |
| December.....  | 1.48               | 1.51           | 1.50           |                |                |                |
| 1913.          |                    |                |                |                |                |                |
| January.....   | 1.55               | 1.52           | 1.51           |                |                |                |
| February.....  | 1.56               | 1.54           | 1.54           | 1.41           | 1.52           | 1.49           |
| March.....     | 1.64               | 1.57           | 1.52           | 1.43           | 1.63           | 1.58           |
| April.....     | 1.66               | 1.60           | 1.52           | 1.42           | 1.57           | 1.53           |
| May.....       | 1.60               | 1.57           | 1.59           | 1.41           | 1.52           | 1.50           |
| May.....       | 1.62               | 1.61           | 1.58           | 1.38           | 1.52           | 1.54           |
| June.....      | 1.53               | 1.50           | 1.61           | 1.43           | 1.50           | 1.51           |
| July.....      | 1.51               | 1.55           | 1.58           | 1.40           | 1.48           | 1.51           |
| August.....    | 1.53               | 1.55           | 1.59           | 1.43           | 1.52           | 1.62           |
| September..... | 1.56               | 1.61           | 1.58           | 1.48           | 1.60           | 1.70           |
| October.....   | 1.57               | 1.48           | 1.52           | 1.49           | 1.59           | 1.49           |
| November.....  | (1.47)             | (1.53)         | (1.55)         | 1.35           | 1.50           | 1.50           |
| December.....  | (1.39)             | (1.41)         | (1.46)         | 1.36           | 1.48           | 1.50           |
| 1914.          |                    |                |                |                |                |                |
| January.....   | (1.47)             | (1.43)         | (1.46)         | 1.31           | 1.49           | 1.49           |
| Average.....   | 1.58               | 1.55           | 1.54           | 1.42           | 1.54           | 1.53           |

Figures in parentheses are repetitions, put in for comparison; they are not included in the averages. For repetition of month of May see note under Table 4.

TABLE 5a.—*Weight of eggs per dozen, by 4-week periods, 1913-14.*

| Period.        | Second laying year. |                |                |                |                |                | First laying year. |                |                |
|----------------|---------------------|----------------|----------------|----------------|----------------|----------------|--------------------|----------------|----------------|
|                | Pen 1.              | Pen 2.         | Pen 3.         | Pen 4.         | Pen 5.         | Pen 6.         | Pen 7.             | Pen 8.         | Pen 9.         |
| 1913.          | <i>Pounds.</i>      | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i>     | <i>Pounds.</i> | <i>Pounds.</i> |
| November.....  | 1.47                | 1.53           | 1.55           | (1.35)         | (1.50)         | (1.50)         |                    |                |                |
| December.....  | 1.39                | 1.41           | 1.46           | (1.36)         | (1.48)         | (1.50)         | 1.36               | 1.40           | 1.45           |
| 1914.          |                     |                |                |                |                |                |                    |                |                |
| January.....   | 1.47                | 1.43           | 1.46           | (1.31)         | (1.49)         | (1.49)         | 1.41               | 1.32           | 1.48           |
| February.....  | 1.68                | 1.49           | 1.62           | 1.49           | 1.57           | 1.58           | 1.43               | 1.42           | 1.51           |
| March.....     | 1.68                | 1.60           | 1.65           | 1.53           | 1.58           | 1.58           | 1.49               | 1.48           | 1.48           |
| April.....     | 1.67                | 1.64           | 1.65           | 1.52           | 1.60           | 1.64           | 1.48               | 1.51           | 1.51           |
| May.....       | 1.74                | 1.69           | 1.65           | 1.56           | 1.59           | 1.71           | 1.53               | 1.54           | 1.54           |
| May.....       | 1.65                | 1.65           | 1.62           | 1.50           | 1.59           | 1.61           | 1.44               | 1.45           | 1.50           |
| June.....      | 1.60                | 1.61           | 1.59           | 1.46           | 1.60           | 1.54           | 1.43               | 1.45           | 1.46           |
| July.....      | 1.63                | 1.57           | 1.63           | 1.47           | 1.60           | 1.58           | 1.51               | 1.42           | 1.43           |
| August.....    | 1.62                | 1.58           | 1.63           | 1.47           | 1.58           | 1.64           | 1.45               | 1.48           | 1.44           |
| September..... | 1.71                | 1.60           | 1.60           | 1.47           | 1.58           | 1.59           | 1.52               | 1.54           | 1.50           |
| October.....   | 1.78                | 1.61           | 1.66           | 1.54           | 1.65           | 1.62           | 1.54               | 1.56           | 1.56           |
| November.....  | (1.47)              | (1.65)         | (1.50)         | 1.60           | 1.71           | 1.74           | 1.61               | 1.54           | 1.54           |
| December.....  |                     | (1.68)         | (1.58)         |                | 1.80           |                | (1.55)             | (1.59)         | (1.58)         |
| 1915.          |                     |                |                |                |                |                |                    |                |                |
| January.....   |                     |                | (1.70)         |                |                | 1.61           | (1.50)             | (1.61)         | (1.63)         |
| Average.....   | 1.65                | 1.59           | 1.62           | 1.50           | 1.60           | 1.62           | 1.46               | 1.47           | 1.50           |

Figures in parentheses are repetitions, put in for comparison; they are not included in the averages. For repetition of month of May see note under Table 4.

TABLE 5b.—*Weight of eggs per dozen by 4-week periods, 1914-15.*

| Period.        | Third laying year. |                |                |                |                |                | Second laying year. |                |                |
|----------------|--------------------|----------------|----------------|----------------|----------------|----------------|---------------------|----------------|----------------|
|                | Pen 1.             | Pen 2.         | Pen 3.         | Pen 4.         | Pen 5.         | Pen 6.         | Pen 7.              | Pen 8.         | Pen 9.         |
| 1914.          | <i>Pounds.</i>     | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i>      | <i>Pounds.</i> | <i>Pounds.</i> |
| November.....  | 1.47               | 1.65           | 1.50           | (1.60)         | (1.71)         | (1.74)         | (1.61)              | (1.54)         | (1.54)         |
| December.....  |                    | 1.68           | 1.58           |                | (1.80)         |                | 1.55                | 1.59           | 1.58           |
| 1915.          |                    |                |                |                |                |                |                     |                |                |
| January.....   |                    |                | 1.70           |                |                | (1.61)         | 1.53                | 1.61           | 1.63           |
| February.....  | 1.90               | 1.69           | 1.71           | 1.56           | 1.76           | 1.64           | 1.52                | 1.60           | 1.62           |
| March.....     | 1.82               | 1.70           | 1.70           | 1.50           | 1.69           | 1.67           | 1.51                | 1.57           | 1.59           |
| April.....     | 1.84               | 1.70           | 1.51           | 1.49           | 1.65           | 1.64           | 1.46                | 1.55           | 1.59           |
| May.....       | 1.73               | 1.64           | 1.61           | 1.50           | 1.65           | 1.60           | 1.45                | 1.51           | 1.56           |
| May.....       | 1.70               | 1.61           | 1.61           | 1.50           | 1.55           | 1.62           | 1.41                | 1.49           | 1.55           |
| June.....      | 1.65               | 1.70           | 1.63           | 1.46           | 1.60           | 1.65           | 1.46                | 1.47           | 1.53           |
| July.....      | 1.71               | 1.53           | 1.63           | 1.48           | 1.60           | 1.62           | 1.44                | 1.46           | 1.51           |
| August.....    | 1.74               | 1.66           | 1.58           | 1.48           | 1.64           | 1.61           | 1.45                | 1.50           | 1.52           |
| September..... | 1.82               | 1.35           | 1.60           | 1.48           | 1.64           | 1.60           | 1.47                | 1.53           | 1.48           |
| October.....   |                    |                |                |                | 1.75           |                | 1.56                |                | 1.67           |
| November.....  |                    |                |                |                | 1.55           | 1.62           |                     |                |                |
| Average.....   | 1.75               | 1.66           | 1.61           | 1.49           | 1.63           | 1.62           | 1.46                | 1.52           | 1.56           |

| Period.        | First laying year. |                |                |                |                |                |                |  |
|----------------|--------------------|----------------|----------------|----------------|----------------|----------------|----------------|--|
|                | Pen 10.            | Pen 11.        | Pen 12.        | Pen 13.        | Pen 14.        | Pen 15.        | Pen 16.        |  |
| 1914.          | <i>Pounds.</i>     | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> |  |
| November.....  |                    |                | 1.44           |                |                |                |                |  |
| December.....  | 1.30               | 1.45           | 1.44           |                |                |                |                |  |
| 1915.          |                    |                |                |                |                |                |                |  |
| January.....   |                    | 1.64           | 1.51           |                |                |                |                |  |
| February.....  | 1.65               | 1.73           | 1.57           | 1.46           | 1.48           |                |                |  |
| March.....     | 1.59               | 1.72           | 1.62           | 1.53           | 1.55           | 1.49           | 1.49           |  |
| April.....     | 1.51               | 1.55           | 1.56           | 1.50           | 1.47           | 1.38           | 1.39           |  |
| May.....       | 1.49               | 1.51           | 1.53           | 1.53           | 1.45           | 1.41           | 1.50           |  |
| May.....       | 1.62               | 1.57           | 1.53           | 1.54           | 1.49           | 1.36           | 1.41           |  |
| June.....      | 1.59               | 1.50           | 1.57           | 1.49           | 1.47           | 1.36           | 1.46           |  |
| July.....      | 1.68               | 1.48           | 1.55           | 1.49           | 1.46           | 1.20           | 1.44           |  |
| August.....    | 1.57               | 1.61           | 1.54           | 1.53           | 1.49           |                | 1.44           |  |
| September..... | 1.70               | 1.51           | 1.43           | 1.55           | 1.46           |                | 1.59           |  |
| October.....   | 1.74               |                | 1.61           | 1.67           | 1.55           |                |                |  |
| November.....  |                    |                |                | 1.65           | 1.54           |                |                |  |
| December.....  |                    |                |                |                |                | 1.32           |                |  |
| 1916.          |                    |                |                |                |                |                |                |  |
| January.....   |                    |                |                | 1.48           | 1.45           |                |                |  |
| February.....  |                    |                |                |                |                | 1.44           |                |  |
| Average.....   | 1.59               | 1.56           | 1.54           | 1.51           | 1.47           | 1.37           | 1.45           |  |

Figures in parentheses are repetitions, put in for comparison; they are not included in the averages. For repetition of month of May see note under Table 4.

The average weight of the eggs is highest in the early spring months, with a gradual decrease in weight to the period of lowest averages, which occur during the summer months. The average weight of a dozen eggs for Pens 1 to 6 was 1.53 pounds during the first year (1912 to 1913), 1.60 pounds for the second year, and 1.63 pounds during the third year. The production of larger eggs during the early spring months and during the second and third as compared with the first year is thought to account in part for the larger and stronger chickens which are said to be procured during the early spring months and from mature stock. It is not apparent that the different rations affected the weight of the eggs except in Pens 9 and 15, where no beef scrap was fed, and in Pen 16, which had only a very small percentage of beef scrap. The eggs from Pen 9 were smaller throughout the year than from the other general-purpose pens during their first laying year, and averaged 0.05 of a pound less per dozen with a similar difference in weight during their second year. The eggs in Pens 15 and 16 were very small. These pens were fed on a ration containing cottonseed meal and the hens did not eat enough feed to produce normal results. This feature is discussed more in detail on page 13. The increased size of the Leghorn eggs from Pens 7 and 8 in 1914, compared with Pen 4 in 1913, goes with the increased weight of the fowls as shown in Table 10, and may be due to the introduction of new blood and to the selection of larger fowls for breeding. The eggs in Pen 8 on free range weighed about the same as those from Pen 7 confined during their first year, but were 0.06 of a pound per dozen heavier in their second year, apparently owing to free range and a greater percentage of beef scrap in the ration.

The average weight of the eggs during the period of low production (fall and early winter) is subject to error during the first two years' work, as it may have been greatly affected by a few individual hens or by the cumulative error in reading the weight of only one or two eggs. To eliminate this latter error during the period of low production the eggs were held until six had accumulated before being weighed in the succeeding experiments. When the egg production during a four-week period is less than 36 eggs no weight is calculated for that period, which accounts for the blanks in Tables 5, 5a, and 5b.

#### DISTRIBUTION OF EGG PRODUCTION.

Tables 6, 6a, and 6b show the percentage of egg production for 13 periods of 4 weeks in each year for all pens. This is calculated on the basis of the maximum, or 100 per cent, being equal to one egg per hen per day. The average percentage of production for two and for three years are also given. The periods are arranged to make them



correspond as nearly as possible in each pen. The exact periods for each pen are given on page 8.

TABLE 6.—*Percentage of egg production for 4-week periods, 1912-13.*

100 PER CENT=1 EGG PER HEN PER DAY.

| Period.        | First laying year. |                  |                  |                  |                  |                  |
|----------------|--------------------|------------------|------------------|------------------|------------------|------------------|
|                | Pen 1.             | Pen 2.           | Pen 3.           | Pen 4.           | Pen 5.           | Pen 6.           |
| 1912.          | <i>Per cent.</i>   | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> |
| November.....  | 36                 | 29               | 16               |                  |                  |                  |
| December.....  | 27                 | 38               | 42               |                  |                  |                  |
| 1913.          |                    |                  |                  |                  |                  |                  |
| January.....   | 18                 | 34               | 43               |                  |                  |                  |
| February.....  | 42                 | 45               | 44               | 43               | 34               | 26               |
| March.....     | 56                 | 51               | 55               | 63               | 54               | 48               |
| April.....     | 58                 | 61               | 50               | 75               | 58               | 59               |
| May.....       | 58                 | 50               | 49               | 70               | 51               | 57               |
| June.....      | 52                 | 49               | 39               | 57               | 42               | 44               |
| July.....      | 42                 | 43               | 28               | 46               | 42               | 43               |
| August.....    | 39                 | 31               | 29               | 42               | 30               | 33               |
| September..... | 38                 | 35               | 20               | 32               | 30               | 28               |
| October.....   | 25                 | 33               | 24               | 26               | 25               | 18               |
| November.....  | 15                 | 20               | 11               | 14               | 21               | 13               |
| December.....  | (3)                | (9)              | (9)              | 7                | 13               | 17               |
|                | (6)                | (7)              | (10)             | 6                | 14               | 20               |
| 1914.          |                    |                  |                  |                  |                  |                  |
| January.....   | (7)                | (7)              | (8)              | 12               | 20               | 15               |
| Average.....   | 39                 | 40               | 34               | 38               | 33               | 30               |

Figures in parentheses are repetitions, put in for comparison; they are not included in the averages. For repetition of month of May see note under Table 4.

TABLE 6a.—*Percentage of egg production for 4-week periods, 1913-14.*

100 PER CENT=1 EGG PER HEN PER DAY.

| Period.             | Second laying year. |                |                |                |                |                | First laying year. |                |                |
|---------------------|---------------------|----------------|----------------|----------------|----------------|----------------|--------------------|----------------|----------------|
|                     | Pen 1.              | Pen 2.         | Pen 3.         | Pen 4.         | Pen 5.         | Pen 6.         | Pen 7.             | Pen 8.         | Pen 9.         |
| 1913.               | <i>Per ct.</i>      | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i>     | <i>Per ct.</i> | <i>Per ct.</i> |
| November.....       | 3                   | 9              | 9              | (7)            | (13)           | (17)           |                    |                |                |
| December.....       | 6                   | 7              | 10             | (6)            | (14)           | (20)           | 37                 | 28             | 9              |
| 1914.               |                     |                |                |                |                |                |                    |                |                |
| January.....        | 7                   | 7              | 8              | (12)           | (20)           | (15)           | 31                 | 35             | 8              |
| February.....       | 26                  | 11             | 21             | 41             | 25             | 21             | 36                 | 43             | 29             |
| March.....          | 27                  | 22             | 26             | 29             | 36             | 36             | 39                 | 57             | 10             |
| April.....          | 48                  | 40             | 37             | 58             | 51             | 44             | 44                 | 70             | 46             |
| May.....            | 38                  | 43             | 34             | 68             | 45             | 45             | 59                 | 73             | 44             |
| June.....           | 47                  | 24             | 31             | 63             | 35             | 27             | 52                 | 62             | 38             |
| July.....           | 37                  | 31             | 26             | 49             | 34             | 43             | 46                 | 59             | 30             |
| August.....         | 28                  | 29             | 19             | 44             | 28             | 32             | 21                 | 43             | 27             |
| September.....      | 26                  | 26             | 20             | 30             | 34             | 27             | 29                 | 24             | 23             |
| October.....        | 23                  | 22             | 20             | 19             | 28             | 19             | 14                 | 25             | 21             |
| November.....       | 13                  | 7              | 16             | 11             | 23             | 15             | 14                 | 27             | 19             |
| December.....       | (1)                 | (1)            | (7)            | 0              | 14             | 8              | 9                  | 19             | 16             |
|                     | (0)                 | (1)            | (2)            | 0              | 2              | 0              | (9)                | (8)            | (9)            |
| 1915.               |                     |                |                |                |                |                |                    |                |                |
| January.....        | (2)                 | (1)            | (3)            | 0              | 0              | 7              | (19)               | (21)           | (7)            |
| Average.....        | 25                  | 21             | 21             | 32             | 27             | 25             | 33                 | 43             | 25             |
| 2-year average..... | 32                  | 30.5           | 27.5           | 35             | 30             | 27.5           |                    |                |                |

Figures in parentheses are repetitions, put in for comparison; they are not included in the averages. For repetition of month of May see note under Table 4.

TABLE 6b.—Percentage of egg production for 4-week periods, 1914-15.

100 PER CENT=1 EGG PER HEN PER DAY.

| Period.             | Third laying year. |                |                |                |                |                | Second laying year. |                |                |
|---------------------|--------------------|----------------|----------------|----------------|----------------|----------------|---------------------|----------------|----------------|
|                     | Pen 1.             | Pen 2.         | Pen 3.         | Pen 4.         | Pen 5.         | Pen 6.         | Pen 7.              | Pen 8.         | Pen 9.         |
| 1914.               | <i>Per ct.</i>     | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i>      | <i>Per ct.</i> | <i>Per ct.</i> |
| November.....       | 1                  | 1              | 7              | (0)            | (14)           | (8)            | (9)                 | (19)           | (16)           |
| December.....       | 0                  | 1              | 2              | (0)            | (2)            | (0)            | 9                   | 8              | 9              |
| 1915.               |                    |                |                |                |                |                |                     |                |                |
| January.....        | 2                  | 1              | 3              | (0)            | (0)            | (7)            | 19                  | 21             | 7              |
| February.....       | 9                  | 6              | 11             | 16             | 21             | 27             | 27                  | 40             | 20             |
| March.....          | 34                 | 26             | 22             | 36             | 36             | 35             | 40                  | 64             | 32             |
| April.....          | 39                 | 41             | 26             | 52             | 46             | 45             | 46                  | 71             | 38             |
| May.....            | 33                 | 36             | 28             | 68             | 36             | 46             | 47                  | 73             | 45             |
| May.....            | 36                 | 28             | 35             | 62             | 35             | 44             | 45                  | 73             | 42             |
| June.....           | 29                 | 26             | 22             | 62             | 37             | 27             | 44                  | 65             | 34             |
| July.....           | 33                 | 19             | 27             | 45             | 28             | 25             | 39                  | 57             | 24             |
| August.....         | 24                 | 20             | 15             | 32             | 25             | 19             | 33                  | 41             | 21             |
| September.....      | 15                 | 7              | 10             | 17             | 15             | 12             | 24                  | 23             | 15             |
| October.....        | 0                  | 1              | 4              | 2              | 9              | 3              | 8                   | 3              | 10             |
| November.....       |                    |                |                | 0              | 7              | 7              | 1                   | 2              | 0              |
| December.....       |                    |                |                | 0              | 0              | 2              |                     |                |                |
| 1916.               |                    |                |                |                |                |                |                     |                |                |
| January.....        |                    |                |                | 7              | 1              | 6              |                     |                |                |
| February.....       |                    |                |                |                |                |                |                     |                |                |
| Average.....        | 20                 | 16             | 16             | 31             | 23             | 23             | 29                  | 42             | 23             |
| 3-year average..... | 28                 | 26             | 24             | 34             | 28             | 26             | 31                  | 43             | 24             |

| Period.             | First laying year. |                |                |                |                |                |                |  |
|---------------------|--------------------|----------------|----------------|----------------|----------------|----------------|----------------|--|
|                     | Pen 10.            | Pen 11.        | Pen 12.        | Pen 13.        | Pen 14.        | Pen 15.        | Pen 16.        |  |
| 1914.               | <i>Per ct.</i>     | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> |  |
| November.....       | 0                  | 0              | 7              |                |                |                |                |  |
| December.....       | 2                  | 3              | 24             |                |                |                |                |  |
| 1915.               |                    |                |                |                |                |                |                |  |
| January.....        | 0                  | 16             | 39             |                |                |                |                |  |
| February.....       | 17                 | 20             | 66             | 31             | 35             |                |                |  |
| March.....          | 33                 | 29             | 60             | 63             | 65             | 10             | 17             |  |
| April.....          | 40                 | 37             | 70             | 67             | 67             | 17             | 25             |  |
| May.....            | 55                 | 47             | 68             | 59             | 69             | 25             | 44             |  |
| May.....            | 54                 | 49             | 61             | 48             | 67             | 17             | 39             |  |
| June.....           | 41                 | 49             | 62             | 48             | 59             | 13             | 34             |  |
| July.....           | 40                 | 46             | 49             | 42             | 53             | 2              | 23             |  |
| August.....         | 35                 | 42             | 41             | 45             | 43             | 3              | 20             |  |
| September.....      | 28                 | 23             | 38             | 38             | 39             | 4              | 12             |  |
| October.....        | 26                 | 5              | 20             | 30             | 34             | 0              | 5              |  |
| November.....       |                    |                |                | 27             | 25             | 2              | 0              |  |
| December.....       |                    |                |                | 7              | 7              | 10             | 2              |  |
| 1916.               |                    |                |                |                |                |                |                |  |
| January.....        |                    |                |                | 13             | 8              | 4              | 8              |  |
| February.....       |                    |                |                |                |                | 11             | 12             |  |
| Average.....        | 29                 | 29             | 46             | 40             | 44             | 9              | 19             |  |
| 3-year average..... |                    |                |                |                |                |                |                |  |

<sup>1</sup> Two-year average.

Figures in parentheses are repetitions, put in for comparison; they are not included in the averages. For repetition of month of May see note under Table 4.

The fall and early winter eggs were largely secured from the pullets, as the production of the yearling hens during these months was very low. The total egg yield of all periods throughout the year is less during the second year, although this difference is neither as large in the Leghorns (Pens 4 and 8) as in the general-purpose breeds (Pens 1, 2, 3, 5, and 6), nor in the late-hatched (Pens 4, 5, and 6) as

in the early-hatched (Pens 1, 2, and 3). Spring is the period of greatest total production. Pen 4 (Leghorns) shows considerably less production during the fall and early winter of their second laying year than was the case with the general-purpose pens, especially Pens 5 and 6, started at the same time as Pen 4. Pens 7 and 8 (Leghorns) also show a slightly decreased production during their second winter period, although not as great a decrease as in Pen 4. This difference is also seen in the comparative feed cost of the eggs, shown in Table 7.

The effect of snow on the ground in lowering the egg yield during their first winter was noticeable in Pen 9, which did not receive any beef scrap. However, the egg yield the second winter in this pen compares favorably with that of Pens 1, 2, and 3 during their second winter. The lack of beef scrap as affecting egg production is discussed more in detail on page 11. The weather during February,

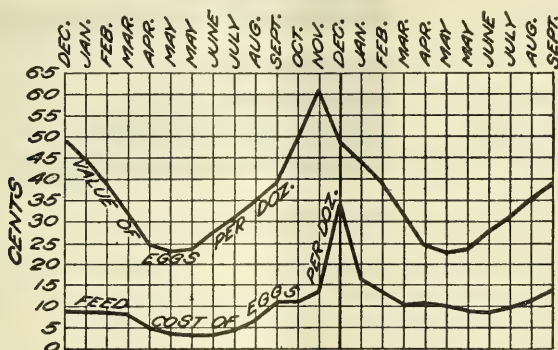


FIG. 3.—Feed cost and value of eggs per dozen in Pen 8. (Last two periods of second year are omitted, as hens had stopped laying.)

1914, was quite mild with practically no snow, while March was cold with considerable snow. Lack of beef scrap also lowered the production throughout the entire year. None of the other differences in the rations appeared to affect the distribution of egg production materially.

#### FEED COST OF EGGS.

The feed cost of a dozen eggs for periods of four weeks each throughout the three years of these experiments is shown in Tables 7, 7a, and 7b. Prices of individual grains in 1917 are from 20 to 100 per cent higher than the prices used in this bulletin. Present prices of grain should be compared to those quoted on page 6 in arriving at the present feed cost of producing eggs. This cost is directly proportional to the egg yield as given in Tables 6, 6a, and 6b. Eggs are produced at the lowest cost in the spring and at the highest cost in the fall and early winter. This high cost in the fall and winter increases very materially with the age of the fowls. Figure 3 shows



the feed cost and value of eggs per dozen in Pen 8 over a period of two years. The feed cost during the first year is fairly constant, but becomes more variable after this period. Figure 4 shows annual comparisons of the Leghorns and general-purpose breeds, also the effect of certain feeds.

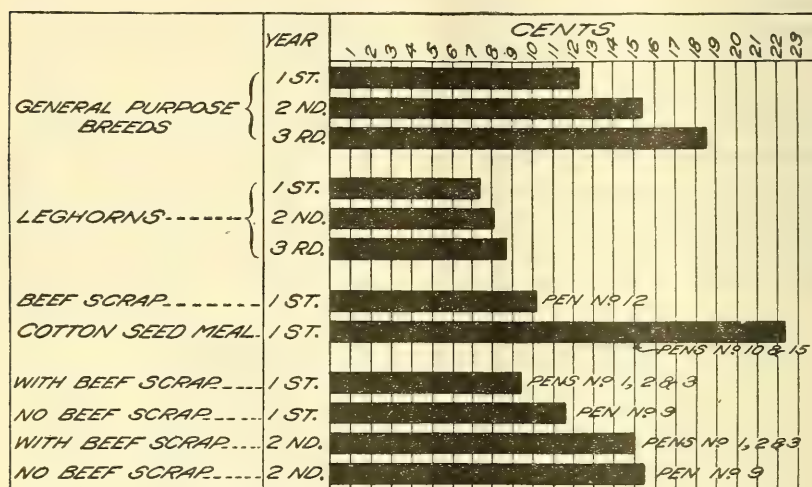


FIG. 4.—Average feed cost of egg production.

TABLE 7.—Feed cost per dozen eggs for 4-week periods, 1912-13.

| Period.        | First laying year. |        |        |        |        |        |
|----------------|--------------------|--------|--------|--------|--------|--------|
|                | Pen 1.             | Pen 2. | Pen 3. | Pen 4. | Pen 5. | Pen 6. |
| 1912.          | Cents.             | Cents. | Cents. | Cents. | Cents. | Cents. |
| November.....  | 11.3               | 13.5   | 28.2   |        |        |        |
| December.....  | 14.7               | 10.5   | 10.7   |        |        |        |
| 1913.          |                    |        |        |        |        |        |
| January.....   | 29.5               | 11.7   | 11.5   |        |        |        |
| February.....  | 11.6               | 6.6    | 11.3   | 7.9    | 13.7   | 18.8   |
| March.....     | 9.2                | 7.5    | 8.5    | 6.1    | 10.4   | 12.0   |
| April.....     | 7.8                | 6.0    | 7.4    | 4.4    | 8.1    | 8.1    |
| May.....       | 6.5                | 5.4    | 7.6    | 4.1    | 7.4    | 7.7    |
| May.....       | 6.2                | 5.1    | 7.6    | 4.5    | 8.9    | 8.9    |
| June.....      | 6.6                | 5.6    | 8.5    | 5.0    | 6.5    | 8.1    |
| July.....      | 7.7                | 7.9    | 11.1   | 7.1    | 9.2    | 11.8   |
| August.....    | 7.5                | 7.4    | 14.7   | 7.4    | 10.5   | 12.5   |
| September..... | 14.1               | 8.1    | 15.3   | 9.9    | 13.3   | 19.7   |
| October.....   | 19.8               | 13.1   | 31.5   | 18.1   | 15.2   | 28.1   |
| November.....  | (102.0)            | (22.9) | (35.0) | 41.0   | 26.7   | 28.7   |
| December.....  | (70.0)             | (44.4) | (38.1) | 41.1   | 29.9   | 23.8   |
| 1914.          |                    |        |        |        |        |        |
| January.....   | (55.0)             | (51.3) | (45.4) | 26.3   | 19.1   | 31.9   |
| Average.....   | 9.9                | 7.7    | 10.9   | 7.3    | 11.2   | 13.2   |

Figures in parentheses are repetitions, put in for comparison; they are not included in the averages. For repetition of month of May see note under Table 4.

TABLE 7a.—*Feed cost per dozen eggs for 4-week periods, 1913-14.*

| Period.        | Second laying year. |               |               |               |               |               | First laying year. |               |               |
|----------------|---------------------|---------------|---------------|---------------|---------------|---------------|--------------------|---------------|---------------|
|                | Pen 1.              | Pen 2.        | Pen 3.        | Pen 4.        | Pen 5.        | Pen 6.        | Pen 7.             | Pen 8.        | Pen 9.        |
| 1913.          | <i>Cents.</i>       | <i>Cents.</i> | <i>Cents.</i> | <i>Cents.</i> | <i>Cents.</i> | <i>Cents.</i> | <i>Cents.</i>      | <i>Cents.</i> | <i>Cents.</i> |
| November.....  | 102.0               | 22.9          | 35.0          | (41.0)        | (26.7)        | (28.7)        | .....              | .....         | .....         |
| December.....  | 70.0                | 44.4          | 38.1          | (41.1)        | (29.9)        | (23.8)        | 7.2                | 9.3           | 28.6          |
| 1914.          |                     |               |               |               |               |               |                    |               |               |
| January.....   | 55.0                | 51.3          | 45.4          | (26.3)        | (19.1)        | (31.9)        | 11.0               | 9.5           | 40.0          |
| February.....  | 12.0                | 33.7          | 17.2          | 6.9           | 15.8          | 21.0          | 10.4               | 8.0           | 10.4          |
| March.....     | 14.0                | 15.7          | 12.8          | 11.1          | 11.5          | 13.8          | 9.3                | 7.1           | 32.6          |
| April.....     | 7.0                 | 7.8           | 10.1          | 5.5           | 8.5           | 11.4          | 6.6                | 4.6           | 5.4           |
| May.....       | 7.5                 | 7.8           | 9.9           | 5.0           | 7.9           | 8.3           | 5.2                | 4.6           | 6.3           |
| June.....      | 6.8                 | 10.0          | 10.2          | 4.5           | 8.8           | 11.9          | 5.4                | 4.0           | 6.3           |
| July.....      | 9.0                 | 10.0          | 13.5          | 5.2           | 9.5           | 9.3           | 5.6                | 4.3           | 8.9           |
| August.....    | 10.3                | 9.8           | 15.5          | 6.4           | 10.6          | 14.2          | 10.8               | 5.0           | 9.4           |
| September..... | 11.1                | 11.9          | 14.7          | 8.1           | 9.8           | 12.6          | 8.1                | 7.1           | 11.5          |
| October.....   | 16.0                | 16.2          | 17.7          | 12.3          | 11.2          | 20.4          | 18.1               | 12.0          | 14.5          |
| November.....  | 41.8                | 52.4          | 22.0          | 23.8          | 19.6          | 30.7          | 22.4               | 11.1          | 18.0          |
| December.....  | (246.0)             | (560.0)       | (40.2)        | 645.0         | 27.6          | 55.5          | 30.2               | 14.7          | 22.8          |
|                |                     | (290.0)       | (175.0)       | .....         | 160.0         | 210.0         | (29.8)             | (33.1)        | (38.2)        |
| 1915.          |                     |               |               |               |               |               |                    |               |               |
| January.....   | (150.0)             | (360.0)       | (90.0)        | 390.0         | 200.0         | 92.1          | (14.5)             | (16.5)        | (57.0)        |
| Average.....   | 14.4                | 14.6          | 16.0          | 8.7           | 13.5          | 16.9          | 8.7                | 6.7           | 11.7          |

Figures in parentheses are repetitions, put in for comparison; they are not included in the averages. For repetition of month of May see note under Table 4.

TABLE 7b.—*Feed cost per dozen eggs for 4-week periods, 1914-15.*

| Period.        | Third laying year. |               |               |               |               |               | Second laying year. |               |               |
|----------------|--------------------|---------------|---------------|---------------|---------------|---------------|---------------------|---------------|---------------|
|                | Pen 1.             | Pen 2.        | Pen 3.        | Pen 4.        | Pen 5.        | Pen 6.        | Pen 7.              | Pen 8.        | Pen 9.        |
| 1914.          | <i>Cents.</i>      | <i>Cents.</i> | <i>Cents.</i> | <i>Cents.</i> | <i>Cents.</i> | <i>Cents.</i> | <i>Cents.</i>       | <i>Cents.</i> | <i>Cents.</i> |
| November.....  | 246.0              | 560.0         | 40.2          | (645.0)       | (27.6)        | (55.5)        | (30.2)              | (14.7)        | (22.8)        |
| December.....  | .....              | 290.0         | 175.0         | .....         | (160.0)       | (210.0)       | 29.8                | 33.1          | 38.2          |
| 1915.          |                    |               |               |               |               |               |                     |               |               |
| January.....   | 150.0              | 360.0         | 90.0          | (390.0)       | (200.0)       | (92.1)        | 14.5                | 16.5          | 57.0          |
| February.....  | 53.6               | 83.0          | 37.1          | 17.9          | 22.4          | 22.9          | 11.4                | 8.1           | 19.0          |
| March.....     | 14.0               | 17.0          | 12.7          | 7.8           | 12.7          | 14.5          | 7.3                 | 5.3           | 9.6           |
| April.....     | 11.2               | 9.9           | 10.3          | 4.9           | 9.8           | 11.9          | 6.1                 | 5.4           | 10.0          |
| May.....       | 10.8               | 9.5           | 9.5           | 4.8           | 11.2          | 10.0          | 5.6                 | 5.1           | 8.1           |
| June.....      | 12.8               | 14.7          | 8.4           | 5.3           | 11.2          | 9.8           | 6.3                 | 4.7           | 8.8           |
| July.....      | 14.0               | 12.7          | 12.4          | 5.2           | 9.9           | 13.3          | 6.3                 | 4.5           | 8.3           |
| August.....    | 14.0               | 22.3          | 11.2          | 6.4           | 14.6          | 18.6          | 7.0                 | 5.0           | 13.8          |
| September..... | 19.2               | 17.2          | 19.9          | 7.4           | 17.0          | 20.9          | 9.8                 | 6.9           | 17.0          |
| October.....   | 25.0               | 38.7          | 28.1          | 11.4          | 21.9          | 27.5          | 11.1                | 9.7           | 23.3          |
| November.....  | .....              | 730.0         | 83.5          | 133.0         | 32.4          | 138.4         | 27.6                | 92.3          | 32.6          |
| December.....  | .....              | .....         | .....         | .....         | 45.7          | 64.4          | 247.0               | 190.0         | 92.3          |
|                | .....              | .....         | .....         | .....         | 910.0         | 256.0         | .....               | .....         | .....         |
| 1916.          |                    |               |               |               |               |               |                     |               |               |
| January.....   | .....              | .....         | .....         | 40.0          | 340.0         | 91.0          | .....               | .....         | .....         |
| February.....  | .....              | .....         | .....         | .....         | .....         | .....         | .....               | .....         | .....         |
| Average.....   | 22.4               | 26.0          | 19.5          | 8.8           | 17.2          | 20.0          | 9.4                 | 7.5           | 15.3          |

TABLE 7b.—*Feed cost per dozen eggs for 4-week periods, 1914-15—Continued.*

| Period.        | First laying year. |               |               |               |               |               |               |
|----------------|--------------------|---------------|---------------|---------------|---------------|---------------|---------------|
|                | Pen 10.            | Pen 11.       | Pen 12.       | Pen 13.       | Pen 14.       | Pen 15.       | Pen 16.       |
| 1914.          | <i>Cents.</i>      | <i>Cents.</i> | <i>Cents.</i> | <i>Cents.</i> | <i>Cents.</i> | <i>Cents.</i> | <i>Cents.</i> |
| November.....  |                    |               | 45.7          |               |               |               |               |
| December.....  | 159.0              | 70.8          | 17.1          |               |               |               |               |
| 1915.          |                    |               |               |               |               |               |               |
| January.....   |                    | 20.0          | 12.1          |               |               |               |               |
| February.....  | 22.4               | 15.4          | 8.1           | 12.7          | 10.8          |               |               |
| March.....     | 10.0               | 10.6          | 9.9           | 7.3           | 7.2           | 31.0          | 18.6          |
| April.....     | 8.1                | 7.9           | 8.8           | 6.7           | 7.0           | 14.3          | 10.4          |
| May.....       | 6.9                | 6.7           | 7.8           | 5.7           | 7.1           | 9.1           | 6.7           |
| May.....       | 8.7                | 7.7           | 8.3           | 6.1           | 7.2           | 15.7          | 7.1           |
| June.....      | 10.1               | 8.9           | 7.5           | 6.9           | 7.4           | 19.3          | 10.2          |
| July.....      | 9.0                | 7.3           | 8.9           | 6.5           | 8.6           | 139.0         | 15.4          |
| August.....    | 11.1               | 11.1          | 10.9          | 7.1           | 8.9           | 9.2           | 17.8          |
| September..... | 12.8               | 19.3          | 11.2          | 8.3           | 10.8          | 7.8           | 27.3          |
| October.....   | 13.4               | 80.2          | 19.8          | 8.7           | 11.4          |               | 66.9          |
| November.....  |                    |               |               | 11.2          | 16.3          | 244.0         |               |
| December.....  |                    |               |               | 40.0          | 52.7          | 36.0          | 240.0         |
| 1916.          |                    |               |               |               |               |               |               |
| January.....   |                    |               |               | 28.0          | 59.0          | 85.0          | 45.0          |
| February.....  |                    |               |               |               |               | 35.0          | 37.0          |
| Average.....   | 13.4               | 11.9          | 10.2          | 8.5           | 9.7           | 31.9          | 18.0          |

Figures in parentheses are repetitions, put in for comparison; they are not included in the averages. For repetition of month of May see note under Table 4.

#### FEED USED IN PRODUCING EGGS.

The amount of feed used in producing a dozen eggs is shown in Tables 8, 8a, and 8b. The cost of this feed for each period is shown in Tables 7, 7a, and 7b. The amount of feed is given in addition to the cost so that the cost can be more readily secured at any time regardless of the comparative price of grains.

TABLE 8.—*Feed per dozen eggs for 4-week periods, 1912-13.*

| Period.        | First laying year. |                |                |                |                |                |
|----------------|--------------------|----------------|----------------|----------------|----------------|----------------|
|                | Pen 1.             | Pen 2.         | Pen 3.         | Pen 4.         | Pen 5.         | Pen 6.         |
| 1912.          | <i>Pounds.</i>     | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> |
| November.....  | 7.0                | 8.3            | 17.3           |                |                |                |
| December.....  | 9.1                | 6.4            | 6.8            |                |                |                |
| 1913.          |                    |                |                |                |                |                |
| January.....   | 18.1               | 7.2            | 7.3            |                |                |                |
| February.....  | 7.1                | 4.1            | 7.1            | 4.8            | 8.7            | 10.7           |
| March.....     | 5.6                | 4.6            | 5.3            | 3.7            | 6.6            | 6.9            |
| April.....     | 4.8                | 3.7            | 4.7            | 2.7            | 5.1            | 4.8            |
| May.....       | 4.2                | 3.5            | 4.8            | 2.7            | 4.9            | 4.5            |
| May.....       | 4.0                | 3.2            | 5.0            | 2.9            | 5.8            | 5.5            |
| June.....      | 4.3                | 3.6            | 5.8            | 3.3            | 4.4            | 5.2            |
| July.....      | 5.1                | 5.1            | 7.3            | 4.6            | 6.2            | 7.6            |
| August.....    | 4.9                | 4.8            | 9.7            | 4.8            | 7.0            | 8.2            |
| September..... | 9.1                | 5.2            | 9.9            | 6.4            | 8.8            | 12.9           |
| October.....   | 13.1               | 8.4            | 20.8           | 11.6           | 10.1           | 18.2           |
| November.....  | (66.2)             | (15.0)         | (22.6)         | 26.6           | 17.6           | 17.6           |
| December.....  | (44.9)             | (28.7)         | (25.0)         | 27.3           | 19.3           | 15.1           |
| 1914.          |                    |                |                |                |                |                |
| January.....   | (35.8)             | (32.9)         | (29.5)         | 16.6           | 12.6           | 20.3           |
| Average.....   | 6.2                | 4.9            | 7.0            | 4.7            | 7.3            | 8.1            |

Figures in parentheses are repetitions, put in for comparison; they are not included in the averages. For repetition of month of May see note under Table 4.



TABLE 8a.—*Feed per dozen eggs for 4-week periods, 1913-14.*

| Period.        | Second laying year. |                |                |                |                |                | First laying year. |                |                |
|----------------|---------------------|----------------|----------------|----------------|----------------|----------------|--------------------|----------------|----------------|
|                | Pen 1.              | Pen 2.         | Pen 3.         | Pen 4.         | Pen 5.         | Pen 6.         | Pen 7.             | Pen 8.         | Pen 9.         |
| 1913.          | <i>Pounds.</i>      | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i>     | <i>Pounds.</i> | <i>Pounds.</i> |
| November.....  | 66.2                | 15.0           | 22.6           | (26.6)         | (17.6)         | (17.6)         | .....              | .....          | .....          |
| December.....  | 44.9                | 28.7           | 25.0           | (27.3)         | (19.3)         | (15.1)         | 4.5                | 6.1            | 19.9           |
| 1914.          |                     |                |                |                |                |                |                    |                |                |
| January.....   | 35.8                | 32.9           | 29.5           | (16.6)         | (12.6)         | (20.3)         | 7.2                | 6.1            | 27.9           |
| February.....  | 7.8                 | 21.0           | 11.2           | 4.5            | 10.1           | 13.1           | 6.4                | 5.0            | 7.3            |
| March.....     | 8.5                 | 9.8            | 8.4            | 7.1            | 7.4            | 8.6            | 6.0                | 4.4            | 22.7           |
| April.....     | 4.5                 | 4.9            | 6.6            | 3.5            | 5.4            | 7.0            | 4.3                | 3.0            | 3.7            |
| May.....       | 5.0                 | 4.9            | 6.4            | 3.1            | 5.2            | 5.2            | 3.3                | 3.0            | 4.4            |
| May.....       | 4.4                 | 6.4            | 6.5            | 2.9            | 5.7            | 7.4            | 3.4                | 2.6            | 4.4            |
| June.....      | 5.7                 | 6.2            | 8.5            | 3.2            | 6.0            | 5.7            | 3.5                | 2.7            | 6.2            |
| July.....      | 6.6                 | 6.1            | 9.8            | 4.0            | 6.7            | 8.3            | 6.8                | 3.2            | 6.5            |
| August.....    | 7.0                 | 7.4            | 9.5            | 5.1            | 6.3            | 7.9            | 5.1                | 4.6            | 8.0            |
| September..... | 9.9                 | 9.8            | 10.7           | 7.7            | 6.9            | 12.8           | 11.9               | 7.4            | 10.1           |
| October.....   | 25.8                | 32.3           | 14.7           | 15.3           | 12.4           | 19.6           | 14.3               | 6.9            | 12.6           |
| November.....  | (154.0)             | (345.0)        | (26.9)         | 432.0          | 17.6           | 36.3           | 19.4               | 9.2            | 15.9           |
| December.....  | .....               | (275.0)        | (116.2)        | .....          | 102.0          | 135.9          | (20.0)             | (20.7)         | (26.7)         |
| 1915.          |                     |                |                |                |                |                |                    |                |                |
| January.....   | (171.3)             | (416.2)        | (113.9)        | 267.5          | 128.4          | 57.6           | (9.8)              | (10.2)         | (39.9)         |
| Average.....   | 9.2                 | 9.2            | 10.3           | 5.6            | 8.6            | 10.6           | 5.6                | 4.2            | 8.2            |

Figures in parentheses are repetitions, put in for comparison; they are not included in the averages. For repetition of month of May see note under Table 4.

TABLE 8b.—*Feed per dozen eggs for 4-week periods, 1914-15.*

| Period.        | Third laying year. |                |                |                |                |                | Second laying year. |                |                |
|----------------|--------------------|----------------|----------------|----------------|----------------|----------------|---------------------|----------------|----------------|
|                | Pen 1.             | Pen 2.         | Pen 3.         | Pen 4.         | Pen 5.         | Pen 6.         | Pen 7.              | Pen 8.         | Pen 9.         |
| 1914.          | <i>Pounds.</i>     | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i>      | <i>Pounds.</i> | <i>Pounds.</i> |
| November.....  | 154.0              | 345.0          | 26.9           | (432.0)        | (17.6)         | (36.3)         | (19.4)              | (9.2)          | (15.9)         |
| December.....  | .....              | 275.0          | 116.2          | .....          | (102.0)        | (135.9)        | 20.0                | 20.7           | 26.7           |
| 1915.          |                    |                |                |                |                |                |                     |                |                |
| January.....   | 171.3              | 416.2          | 113.9          | (267.5)        | (128.4)        | (57.6)         | 9.8                 | 10.2           | 39.9           |
| February.....  | 34.4               | 52.5           | 25.2           | 12.3           | 14.5           | 14.7           | 7.8                 | 5.1            | 13.3           |
| March.....     | 8.9                | 10.4           | 8.6            | 5.3            | 8.2            | 9.4            | 4.9                 | 3.3            | 6.7            |
| April.....     | 7.4                | 6.1            | 7.0            | 3.4            | 6.3            | 7.7            | 4.1                 | 3.3            | 7.0            |
| May.....       | 6.9                | 5.9            | 6.4            | 3.2            | 7.2            | 6.5            | 3.7                 | 3.2            | 5.6            |
| May.....       | 7.8                | 8.9            | 5.6            | 3.6            | 7.0            | 6.3            | 4.1                 | 2.9            | 6.1            |
| June.....      | 8.5                | 7.8            | 8.2            | 3.4            | 6.2            | 8.6            | 4.1                 | 2.8            | 5.8            |
| July.....      | 8.6                | 13.6           | 7.4            | 4.3            | 9.2            | 12.3           | 4.6                 | 3.2            | 9.6            |
| August.....    | 11.9               | 10.6           | 13.2           | 5.0            | 10.6           | 13.6           | 6.5                 | 4.4            | 11.8           |
| September..... | 15.8               | 24.0           | 19.0           | 7.9            | 13.8           | 17.7           | 7.3                 | 6.3            | 16.2           |
| October.....   | .....              | 450.5          | 54.0           | 88.7           | 20.7           | 90.4           | 18.3                | 58.9           | 22.7           |
| November.....  | .....              | .....          | .....          | .....          | 28.9           | 41.0           | 162.7               | 117.9          | 64.5           |
| December.....  | .....              | .....          | .....          | 720.0          | 585.5          | 165.0          | .....               | .....          | .....          |
| 1916.          |                    |                |                |                |                |                |                     |                |                |
| January.....   | .....              | .....          | .....          | 27.1           | 218.0          | 59.6           | .....               | .....          | .....          |
| February.....  | .....              | .....          | .....          | .....          | .....          | .....          | .....               | .....          | .....          |
| Average.....   | 14.1               | 16.0           | 13.1           | 6.0            | 11.0           | 12.9           | 6.2                 | 4.7            | 10.7           |

TABLE 8C.—*Feed per dozen eggs for 4-week periods, 1914-15—Continued.*

| Period.        | First laying year. |                |                |                |                |                |                |
|----------------|--------------------|----------------|----------------|----------------|----------------|----------------|----------------|
|                | Pen 10.            | Pen 11.        | Pen 12.        | Pen 13.        | Pen 14.        | Pen 15.        | Pen 16.        |
| 1914.          | <i>Pounds.</i>     | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> |
| November.....  |                    |                | 28.1           |                |                |                |                |
| December.....  | 105.7              | 47.3           | 10.4           |                |                |                |                |
| 1915.          |                    |                |                |                |                |                |                |
| January.....   |                    | 13.2           | 7.5            | 8.3            | 7.0            |                |                |
| February.....  | 15.1               | 10.4           | 5.1            | 4.8            | 4.6            |                |                |
| March.....     | 6.8                | 7.1            | 6.1            | 4.4            | 4.5            | 20.7           | 12.4           |
| April.....     | 5.5                | 5.3            | 5.5            | 3.8            | 4.6            | 9.7            | 7.1            |
| May.....       | 4.7                | 4.5            | 4.9            | 4.1            | 4.6            | 6.2            | 4.5            |
| June.....      | 5.8                | 5.1            | 5.2            | 4.5            | 4.7            | 10.5           | 4.8            |
| July.....      | 6.8                | 5.9            | 4.7            | 4.3            | 5.4            | 12.9           | 6.8            |
| August.....    | 6.0                | 4.8            | 5.5            | 4.7            | 5.7            | 92.1           | 10.3           |
| September..... | 7.5                | 7.3            | 6.7            | 5.5            | 6.9            | 62.6           | 11.8           |
| October.....   | 8.6                | 12.7           | 6.9            | 5.9            | 7.4            | 51.9           | 18.1           |
| November.....  | 9.0                | 53.3           | 12.4           | 7.4            | 10.5           |                | 44.6           |
| December.....  |                    |                |                | 27.0           | 34.2           | 163.6          |                |
|                |                    |                |                | 18.6           | 37.9           | 24.0           | 159.0          |
| 1916.          |                    |                |                |                |                |                |                |
| January.....   |                    |                |                |                |                | 57.8           | 30.2           |
| February.....  |                    |                |                |                |                | 23.4           | 25.1           |
| Average.....   | 9.0                | 7.9            | 6.3            | 5.6            | 6.2            | 21.4           | 12.0           |

Figures in parentheses are repetitions, put in for comparison; they are not included in the averages. For repetition of month of May, see note under Table 4.

#### VALUE OF THE EGGS FROM EACH PEN.

The average value of the eggs per hen, the value over feed cost, and the average yearly value of eggs per dozen for each pen is shown

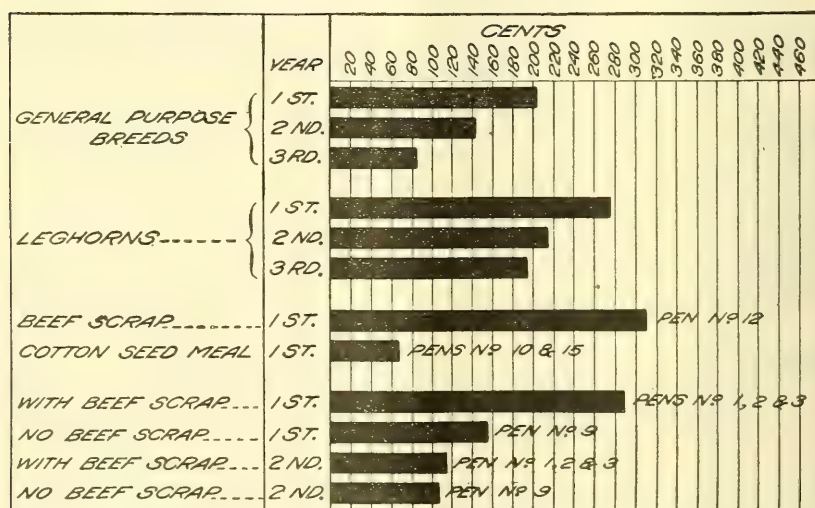


FIG. 5.—Average yearly value of eggs per hen over feed cost.

in Table 9, and some interesting comparisons of breeds and feeds are seen in figure 5. The material difference between the excess of egg value over feed cost of hens in the first year and that in the second

and third years is clearly shown. The average value over feed cost the first year from Pens 1 to 6 exceeded that of the second year by \$1.15 per hen, while the second-year average exceeded the third year by 62 cents. The average decrease from the first to the second year of the early-hatched general-purpose pens (Nos. 1 to 3) was \$1.73, compared with 58 cents in the late-hatched pens (Nos. 5 and 6). In their third year the average decrease was 76 cents in the early-hatched pens and 61 cents in the late-hatched pens. The total value of the eggs for two years over cost of feed from Pen 4 (Leghorns) was \$4.90, against \$4.34 in Pen 2, the highest of any of the general-purpose pens. The total value over feed cost for three years was \$6.84 for Pen 4 (Leghorns), against \$4.45 for Pen 2. The value of the eggs over feed cost during their third laying year is very much greater for Leghorns than for general-purpose fowls, as shown in this table. The highest average value over feed cost made by any pen during its pullet year was \$3.41 in Pen 8 (1914), also a Leghorn pen, which is 15 cents per hen higher than the highest general-purpose pen (Pen 2). Present prices of eggs and feeds should be carefully compared in considering the following table.

TABLE 9.—Average value of eggs per hen and per dozen.

| Pen.         | 1912-13               |                              |                          | 1913-14               |                              |                          | 1914-15               |                              |                          |
|--------------|-----------------------|------------------------------|--------------------------|-----------------------|------------------------------|--------------------------|-----------------------|------------------------------|--------------------------|
|              | Annual value per hen. | Annual value over feed cost. | Average value per dozen. | Annual value per hen. | Annual value over feed cost. | Average value per dozen. | Annual value per hen. | Annual value over feed cost. | Average value per dozen. |
|              |                       |                              | <i>Cents.</i>            |                       |                              | <i>Cents.</i>            |                       |                              | <i>Cents.</i>            |
| 1.....       | \$4.03                | \$2.86                       | 33.9                     | \$2.32                | \$1.25                       | 31.0                     | \$1.70                | \$0.39                       | 28.9                     |
| 2.....       | 4.20                  | 3.26                         | 34.6                     | 2.03                  | 1.08                         | 31.3                     | 1.34                  | .11                          | 28.3                     |
| 3.....       | 3.66                  | 2.50                         | 34.5                     | 2.11                  | 1.08                         | 32.6                     | 1.52                  | .65                          | 30.5                     |
| 4.....       | 3.59                  | 2.72                         | 30.4                     | 3.03                  | 2.18                         | 30.9                     | 2.78                  | 1.94                         | 29.1                     |
| 5.....       | 3.33                  | 2.17                         | 32.3                     | 2.82                  | 1.67                         | 33.1                     | 2.14                  | .95                          | 30.9                     |
| 6.....       | 3.21                  | 1.88                         | 31.9                     | 2.54                  | 1.22                         | 32.6                     | 2.11                  | .71                          | 30.0                     |
| Average..... | 3.67                  | 2.56                         | 32.9                     | 2.47                  | 1.41                         | 31.9                     | 1.93                  | .79                          | 29.6                     |
| 7.....       |                       |                              |                          | 3.33                  | 2.45                         | 32.9                     | 2.76                  | 1.92                         | 30.9                     |
| 8.....       |                       |                              |                          | 4.29                  | 3.41                         | 32.7                     | 3.74                  | 2.81                         | 30.1                     |
| 9.....       |                       |                              |                          | 2.43                  | 1.55                         | 32.5                     | 2.14                  | 1.07                         | 30.8                     |
| 10.....      |                       |                              |                          |                       |                              |                          | 2.49                  | 1.39                         | 30.4                     |
| 11.....      |                       |                              |                          |                       |                              |                          | 2.54                  | 1.53                         | 29.8                     |
| 12.....      |                       |                              |                          |                       |                              |                          | 4.58                  | 3.14                         | 32.3                     |
| 13.....      |                       |                              |                          |                       |                              |                          | 3.98                  | 2.96                         | 32.8                     |
| 14.....      |                       |                              |                          |                       |                              |                          | 4.35                  | 3.03                         | 32.0                     |
| 15.....      |                       |                              |                          |                       |                              |                          | .87                   | 1.04                         | 30.3                     |
| 16.....      |                       |                              |                          |                       |                              |                          | 1.67                  | .63                          | 29.0                     |

<sup>1</sup> The minus sign denotes a loss.

The averages for Pens 7 to 16 omitted; see note under Table 2. Note present prices of eggs and feed.

Quotations of nearby eggs on the New York wholesale market were used in calculating the market value of these eggs. The prices of a dozen eggs used in this bulletin for each year (13 periods of 4 weeks



each), beginning November 1, are as follows: 61, 49, 44, 38.5, 31.5, 24.5, 23.5, 24, 27.5, 30.5, 35, 39, and 49 cents, with an average monthly price for the year of 36.7 cents. However, farmers do not usually receive the prices quoted for "nearby" eggs, the best of their eggs being sold as "firsts." The quotations for "firsts" shipped to the New York market were as follows for the corresponding periods, beginning November 1: 40, 39, 35.5, 31, 30.5, 20.5, 20.5, 21.5, 22.5, 23.5, 25, 27.5, and 29 cents, or a monthly average of 28.2 cents. Using the latter figures, the average value over feed cost of eggs produced in 1912-1913 (their pullet year) in Pens 1 to 6 was \$1.51, against \$2.56 for nearby eggs, and 93 cents, against \$1.41 in 1913-1914 (their second year). The average figured on this quotation for Pens 7 to 9 in 1914 would be \$1.80, as against \$2.47 for the nearby eggs. It would be necessary for a poultryman to secure the prices quoted on nearby eggs in order to make a fair profit on the basis of the feed costs given in this bulletin.

#### BROODINESS IN FOWLS.

Broodiness has a material bearing on egg production. In this work the broody hens were removed to small crates to break up their desire to sit. The number of times that hens in each pen were put into the broody coops is shown in Table 2. The length of time that the hens were thus confined varied from 3 to 10 days. Pen 5 contained the largest number of broody hens, there having been 111 instances in 1913, 82 in 1914, and 46 in 1915. Pen 3, which had the next highest number, contained 14 Buff Orpingtons, among which broodiness was much more frequent than among the 16 Rhode Island Reds which made up the rest of the pen. The 11 Orpingtons which were in the pen throughout the year (1912-1913) became broody 56 times, an average of 5.2 times per hen, against 1.7 times per hen among the Rhode Island Reds. Five of the Rhode Island Reds did not become broody during the year, while all the Orpingtons were broody at least three times. This undoubtedly lowered the egg yield materially in Pen 3. Two or more of the Orpingtons were broody during every month of the year except November, while practically all of the broodiness among the Rhode Island Reds occurred between the end of March and the first of August. The proportion of Orpingtons in the other pens was comparatively small, but this same tendency to excessive broodiness has been noted in practically all the Buff Orpingtons used at the farm.

The broodiness in Pen 1 (Rhode Island Reds) in the hens which lived through the year (1912-13) was 2.3 times per hen, which was more than that of the Rhode Island Reds in Pen 3. The Barred Plymouth Rocks in Pen 5 were broody more times than hens of this breed in any of the other pens. The greatest broodiness occurred in

Pens 3 and 5, where a very large proportion of corn meal (about 65 per cent) was fed in the mash. The statement is often made that the number of broody hens can be increased by feeding freely on corn and corn meal. This would appear to be verified by the total broodiness in Pens 3 and 5, all breeds considered; but it is not true of the Rhode Island Reds in Pen 3 compared with those in Pen 1. Broodiness in the hens in their first, compared with their second laying year, averaged about the same for Pens 1 to 6, increasing slightly during the second year in Pens 1, 4, and 6, and decreasing in the other pens. Broodiness decreased very materially in 1915 during the third laying year. The percentage of hens of each breed broody before April 1 of their pullet year from the early-maturing pens (Nos. 1 to 3) was practically the same as from the late-maturing pens (Nos. 5 and 6) except in the Buff Orpingtons, where the percentage was twice as great in the early-maturing pens.

Broodiness is probably largely an individual characteristic, more or less affected by strains, variety, or breed, and by the quantity of corn or corn meal in the ration, but not materially affected by ordinary differences in rations. Further observations on this characteristic are being made in the feeding pens and in a pen of Buff Orpingtons in which trap-nest records of the hens are kept. Broody hens are occasionally found among the White Leghorns, as shown in all of the White Leghorn pens in the year 1913-14. Freedom from broodiness accounts for the higher egg production of Leghorns during the spring and summer, compared with the general-purpose breeds. Frequent broodiness is an undesirable trait in hens kept only for egg production, but may be of considerable value in flocks where natural methods of incubation and brooding are used.

#### EFFECT OF THE MOLT ON EGG YIELD.

Molting materially affects the egg yield, as hens take from 3 to 5 months to molt and lay few if any eggs while molting. The period of molting begins usually about the first of August, but apparently varies somewhat with the season. The pullets started to molt earlier in 1914 than in 1913. The period of molting was from 3 to 6 weeks longer in the second laying year than in the first, and was still somewhat longer in the third than in the second year, while the accompanying period of nonproduction was materially increased in the third year. The late-maturing pens started to molt later than the early-maturing pens, but took about the same average time to molt. No material effect on the molting was apparent from the various rations used, although the molting period varied slightly in all of the pens. More records of the molting of hens are being kept both in the feeding pens and in breeding pens, where individual records of egg yield of each hen are kept.

A feeding test covering four months made in 1913 in a mixed flock of 70 general-purpose pure-bred hens from 1 to 3 years of age, showed that no material benefit in molting was secured by the addition of 10 per cent of linseed meal to the mash. The length of the molting period and the egg yield were practically the same as in the check pen, although the pen receiving the linseed meal produced more eggs during the first part of the molting period and their feathers appeared smoother and more glossy during the entire period.

#### VARIATION IN WEIGHT OF THE HENS.

Table 10 shows the average weight of the hens in Pens 1 to 6 for three years; in Pens 7 to 9 for two years; and for one year in the rest of the pens. The period of greatest average weight occurs in the spring, while the lowest average weight is during the molting period, which is also true of the weight of the eggs. The average weights for each year are given at the bottom of the table. The figures show a tendency for the hens of the general-purpose breeds, especially the Barred Plymouth Rocks and the White Wyandottes, to become too fat. The increase in the average monthly weight of hens of the general-purpose breeds in their second over their first year was about 0.5 of a pound, compared with an average increase of only 0.16 of a pound for the Leghorns. From their second to the third year the average increase in the general-purpose pens was 0.22 of a pound, compared with 0.17 in Pen 4 (Leghorns). The tendency of the method of feeding in Pen 6 to keep the hens too fat is shown in the average monthly weights of this pen, which exceeded all the other general-purpose pens by 0.45 of a pound, or about 8 per cent. The average weights and the increase in weight from the second to third year are largest in this pen.

Pen 9, which did not receive any beef scrap, had a monthly average weight of 0.79 of a pound less than the average of the other general-purpose hens during their first year. The increase in weight, however, from the first to the second year in this nonbeef-scrap pen was 0.55 of a pound, or about the same as in the beef-scrap pens. Pens 10 and 11, fed cottonseed meal, averaged 1 pound less in weight than Pen 12, fed beef scrap. The average weight of Pens 15 and 16, also cottonseed-meal pens, is much below the average of the beef-scrap pens. The hens in the pens fed cottonseed meal were thin and in poor flesh all the time. This was probably partly due to the fact that these hens did not like the cottonseed meal and ate a very small amount of the mash. Their total feed consumption was considerably below that of the beef-scrap pens. The results secured with cottonseed meal are discussed more in detail on page 13.



TABLE 10.—*Monthly average weight per hen.*

| Month.           | Pen 1.      | Pen 2.      | Pen 3.      | Pen 4.      | Pen 5.      | Pen 6.      | Pen 7.      | Pen 8.      | Pen 9.      | Pen 10.     | Pen 11.     | Pen 12.     | Pen 13.     | Pen 14.     | Pen 15.     | Pen 16.     |
|------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
|                  | <i>Lbs.</i> | <i>Lbs.</i> | <i>Lbs.</i> | <i>Lbs.</i> | <i>Lbs.</i> | <i>Lbs.</i> | <i>Lbs.</i> | <i>Lbs.</i> | <i>Lbs.</i> | <i>Lbs.</i> | <i>Lbs.</i> | <i>Lbs.</i> | <i>Lbs.</i> | <i>Lbs.</i> | <i>Lbs.</i> | <i>Lbs.</i> |
| 1912.            |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |
| November.....    | 5.45        | 5.22        | 4.83        | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| December.....    | 5.17        | 5.63        | 5.56        | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| 1913.            |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |
| January.....     | 5.56        | 5.67        | 5.73        | 3.23        | 5.65        | 6.12        | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| February.....    | 5.88        | 5.78        | 5.91        | 3.28        | 6.04        | 6.17        | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| March.....       | 6.06        | 6.02        | 5.82        | 3.37        | 6.14        | 6.28        | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| April.....       | 6.11        | 6.29        | 5.92        | 3.36        | 5.88        | 6.41        | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| May.....         | 5.83        | 6.08        | 5.63        | 3.38        | 5.78        | 6.41        | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| June.....        | 5.73        | 6.08        | 5.47        | 3.18        | 5.76        | 6.15        | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| July.....        | 5.65        | 6.13        | 5.45        | 3.16        | 5.40        | 6.01        | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| August.....      | 5.39        | 5.84        | 5.28        | 3.14        | 5.40        | 5.96        | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| September.....   | 5.46        | 5.98        | 5.47        | 3.10        | 5.55        | 6.07        | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| October.....     | 5.85        | 6.19        | 5.77        | 3.04        | 5.61        | 5.96        | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| November.....    | 5.56        | 5.81        | 5.71        | 3.18        | 5.58        | 6.17        | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| December.....    | 6.00        | 5.85        | 6.03        | 3.40        | 6.16        | 6.50        | 3.40        | 3.32        | 5.36        | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| 1914.            |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |
| January.....     | 6.45        | 6.25        | 6.30        | 3.59        | 6.32        | 6.75        | 3.42        | 3.29        | 5.43        | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| February.....    | 7.01        | 6.92        | 6.80        | 3.43        | 6.70        | 7.15        | 3.40        | 3.31        | 5.67        | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| March.....       | 6.86        | 7.06        | 6.81        | 3.30        | 6.79        | 7.22        | 3.48        | 3.47        | 5.53        | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| April.....       | 6.80        | 6.83        | 6.33        | 3.38        | 6.59        | 7.16        | 2.92        | 3.50        | 5.18        | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| May.....         | 6.38        | 6.85        | 5.73        | 3.43        | 6.37        | 6.66        | 3.15        | 3.50        | 4.76        | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| June.....        | 6.34        | 6.28        | 5.52        | 3.36        | 6.27        | 6.65        | 3.05        | 3.31        | 4.67        | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| July.....        | 6.47        | 6.23        | 5.57        | 3.39        | 6.21        | 6.63        | 3.03        | 3.32        | 4.58        | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| August.....      | 6.41        | 6.42        | 5.74        | 3.25        | 6.00        | 6.57        | 3.18        | 3.19        | 4.39        | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| September.....   | 6.36        | 6.30        | 5.85        | 3.03        | 6.11        | 6.30        | 3.22        | 3.13        | 4.55        | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| October.....     | 5.95        | 5.97        | 5.90        | 3.09        | 6.20        | 6.53        | 3.16        | 3.29        | 4.67        | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| November.....    | 5.97        | 5.70        | 6.07        | 3.14        | 6.00        | 6.44        | 3.51        | 3.52        | 5.42        | 3.44        | 3.70        | 3.38        | .....       | .....       | .....       | .....       |
| December.....    | 6.10        | 5.76        | 5.98        | 3.23        | 5.93        | 6.64        | 3.68        | 3.58        | 5.62        | 3.71        | 3.91        | 4.37        | .....       | .....       | .....       | .....       |
| 1915.            |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |
| January.....     | 6.48        | 6.28        | 6.57        | 3.69        | 6.66        | 7.26        | 3.81        | 3.61        | 5.69        | 4.01        | 4.64        | 5.37        | 4.66        | 4.55        | .....       | .....       |
| February.....    | 6.92        | 6.93        | 7.24        | 3.90        | 6.92        | 7.63        | 3.76        | 3.95        | 6.02        | 4.35        | 4.83        | 5.53        | 5.08        | 4.79        | .....       | .....       |
| March.....       | 7.18        | 7.54        | 7.35        | 3.67        | 6.90        | 7.51        | 3.54        | 3.85        | 5.86        | 4.34        | 4.63        | 5.39        | 5.15        | 4.74        | 4.76        | 4.65        |
| April.....       | 7.14        | 7.12        | 6.74        | 3.61        | 6.82        | 7.42        | 3.45        | 3.68        | 5.63        | 4.33        | 4.30        | 5.57        | 5.19        | 4.61        | 4.52        | 4.22        |
| May.....         | 6.74        | 6.73        | 5.93        | 3.57        | 6.57        | 7.27        | 3.10        | 3.75        | 5.53        | 4.27        | 4.03        | 5.68        | 4.99        | 4.71        | 3.82        | 3.96        |
| June.....        | 6.69        | 6.82        | 5.88        | 3.53        | 6.48        | 6.89        | 3.12        | 3.82        | 5.75        | 4.35        | 4.22        | 5.55        | 5.03        | 4.76        | 3.60        | 3.83        |
| July.....        | 6.45        | 6.56        | 5.98        | 3.42        | 6.44        | 6.86        | 3.13        | 3.75        | 5.43        | 4.21        | 4.21        | 5.57        | 4.81        | 4.79        | 3.58        | 3.74        |
| August.....      | 6.44        | 6.55        | 5.81        | 3.40        | 6.55        | 6.83        | 3.16        | 3.53        | 5.24        | 4.18        | 4.13        | 5.52        | 5.02        | 4.60        | 3.51        | 3.77        |
| September.....   | 6.63        | 6.43        | 5.87        | 3.29        | 6.43        | 6.69        | 3.30        | 3.53        | 5.18        | 4.43        | 4.24        | 5.41        | 4.97        | 4.64        | 3.41        | 3.84        |
| October.....     | 6.30        | 6.00        | 5.55        | 3.23        | 6.03        | 6.38        | 3.45        | 3.41        | 5.44        | 4.48        | 4.23        | 5.24        | 4.89        | 4.58        | 3.56        | 3.84        |
| November.....    | .....       | .....       | .....       | 3.19        | 6.13        | 6.50        | 3.20        | 3.14        | 5.59        | .....       | .....       | .....       | 4.86        | 4.63        | 3.86        | 3.92        |
| December.....    | .....       | .....       | .....       | 3.42        | 6.26        | 6.94        | .....       | .....       | .....       | .....       | .....       | .....       | 4.75        | 4.36        | 4.08        | 4.29        |
| 1916.            |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |
| January.....     | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | 4.15        | 4.68        |
| February.....    | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | 4.26        | 4.57        |
| Annual averages: |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |
| 1913.....        | 5.68        | 5.91        | 5.57        | 3.23        | 5.75        | 6.18        | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| 1914.....        | 6.38        | 6.40        | 6.02        | 3.30        | 6.29        | 6.72        | 3.24        | 3.35        | 5.08        | .....       | .....       | .....       | .....       | .....       | .....       | .....       |
| 1915.....        | 6.58        | 6.54        | 6.27        | 3.47        | 6.51        | 7.01        | 3.40        | 3.61        | 5.58        | 4.18        | 4.25        | 5.21        | 4.95        | 4.65        | 3.92        | 4.11        |

## BALANCED RATIONS.

The proportion of grain and mash, the cost of 100 pounds of the ration, and the nutritive ratio are given in Table 11. The cost of 100 pounds of feed from the different rations varies somewhat according to the proportion of mash and grain and to the nature of the ration, although this difference is not large except in Pen 9, in which the feed is from 10 to 20 cents per 100 pounds cheaper than in the other pens. The nutritive ratio and the cost of the ration in the cottonseed pens (Nos. 10, 11, 15, and 16) was quite low, but the cost of production was very high. The cost of the ration in Pen 9 is the lowest because it does not contain beef scrap, but this ration produced eggs at the highest cost per dozen during the pullet year

in the pens with which it is directly comparable (Nos. 1, 2, and 3 in 1912-1913).

The lower the nutritive ratio the higher the cost of feed per 100 pounds, because of the higher protein content. The nutritive ratio widened considerably in 1915 in all the pens which were allowed to balance their own ration (Nos. 3, 4, and 7), regardless of whether it was their second or third laying year. The hens apparently did not relish the beef scrap as well in 1915 as in the previous year, although the same brand of beef scrap was used. This widening of the ration in Pens 3, 4, and 7, compared with Pens 5 and 8 where the beef scrap was constant, did not change the relative position of these pens in cost of egg production, but may have tended to lower the actual production. The highest-priced ration, that used in Pen 6, was high in price because of the small proportion of ground feed, and produced eggs at the highest cost of any pen during its first two years, regardless of conditions. The rations fed in the different pens are given in Table 1.

TABLE 11.—*Proportion of grain and mash in ration, cost per 100 pounds, and nutritive ratio.*

| Year. | Pen. | Ration.         |                 |                            | Nutri-<br>tive<br>ratio. | Year. | Pen. | Ration.         |                 |                            | Nutri-<br>tive<br>ratio. |
|-------|------|-----------------|-----------------|----------------------------|--------------------------|-------|------|-----------------|-----------------|----------------------------|--------------------------|
|       |      | Grain.          | Mash.           | Cost<br>per 100<br>pounds. |                          |       |      | Grain.          | Mash.           | Cost<br>per 100<br>pounds. |                          |
|       |      | <i>Percent.</i> | <i>Percent.</i> |                            |                          |       |      | <i>Percent.</i> | <i>Percent.</i> |                            |                          |
| 1913  | 1    | 65              | 35              | \$1.58                     | 1:4.5                    | 1914  | 7    | 53              | 47              | \$1.56                     | 1:4.7                    |
| 1914  |      | 56              | 44              | 1.57                       | 1:4.0                    | 1915  |      | 45              | 55              | 1.50                       | 1:6.4                    |
| 1915  |      | 45              | 55              | 1.59                       | 1:3.4                    |       |      |                 |                 |                            |                          |
| 1913  | 2    | 76              | 24              | 1.59                       | 1:5.6                    | 1914  | 8    | 57              | 43              | 1.58                       | 1:4.5                    |
| 1914  |      | 58              | 42              | 1.59                       | 1:4.3                    | 1915  |      | 52              | 48              | 1.60                       | 1:4.2                    |
| 1915  |      | 47              | 53              | 1.62                       | 1:3.7                    | 1914  | 9    | 70              | 30              | 1.43                       | 1:7.8                    |
|       |      |                 |                 |                            |                          | 1915  |      | 52              | 48              | 1.43                       | 1:7.4                    |
| 1913  | 3    | 64              | 36              | 1.56                       | 1:5.5                    | 1915  | 10   | 61              | 39              | 1.49                       | 1:4.9                    |
| 1914  |      | 52              | 48              | 1.55                       | 1:5.1                    |       |      |                 |                 |                            |                          |
| 1915  |      | 43              | 57              | 1.49                       | 1:6.9                    | 1915  | 11   | 54              | 46              | 1.50                       | 1:4.6                    |
| 1913  | 4    | 67              | 33              | 1.57                       | 1:5                      | 1915  | 12   | 48              | 52              | 1.61                       | 1:4.1                    |
| 1914  |      | 54              | 46              | 1.56                       | 1:4.8                    |       |      |                 |                 |                            |                          |
| 1915  |      | 50              | 50              | 1.48                       | 1:7.7                    | 1915  | 13   | 50              | 50              | 1.51                       | 1:4.5                    |
| 1913  | 5    | 59              | 41              | 1.53                       | 1:5.2                    | 1915  | 14   | 46              | 54              | 1.57                       | 1:4.1                    |
| 1914  |      | 47              | 53              | 1.57                       | 1:4.7                    |       |      |                 |                 |                            |                          |
| 1915  |      | 43              | 57              | 1.57                       | 1:4.5                    | 1915  | 15   | 56              | 44              | 1.49                       | 1:4.6                    |
| 1913  | 6    | 84              | 16              | 1.63                       | 1:4.8                    | 1915  | 16   | 69              | 31              | 1.50                       | 1:5.4                    |
| 1914  |      | 74              | 26              | 1.60                       | 1:4.9                    |       |      |                 |                 |                            |                          |
| 1915  |      | 73              | 27              | 1.55                       | 1:5.9                    |       |      |                 |                 |                            |                          |

The nutritive ratios are narrower in all the pens except Pen 6 in their second year, especially in Pens 1 and 2, because the proportion of mash was considerably increased. These ratios are still narrower in their third year (1915), except in those pens allowed to select their own mash constituents. The feeds and method of feeding have as much if not more influence on results as the nutritive ratio, as shown in the case of Pen 9, which has a very wide nutritive ratio

and one which is supposed to represent a fattening ration, but the birds gained less in weight and were thinner throughout the year in this pen than in any of the other general-purpose pens (see Table 10). This ration, however, was deficient in animal protein. The hens increased more in weight and were fatter in Pen 6 than in any other pen, although the nutritive ratio was lower in this pen than in several of the other general-purpose pens. However, with similar methods of feeding and normal rations, the wider nutritive ratios represent the most fattening rations. A nutritive ratio of about 1 to 4.5 has given good results in all of these experiments, although satisfactory results were secured on rations having widely varying ratios.

The digestible nutrients in 100 pounds of the various feeds used are shown in Table 12, while Table 13 shows these digestible nutrients in 100 pounds of the actual feed or ration given to each pen during these experiments. The digestibility of the feeds in these tables is based on experiments conducted with farm animals, as no figures of this nature are available on poultry.

TABLE 12.—*Digestible nutrients in 100 pounds of feeds used.*

| Feed.          | Crude protein. | Carbo-hydrates. | Fat.           | Feed.               | Crude protein. | Carbo-hydrates. | Fat.           |
|----------------|----------------|-----------------|----------------|---------------------|----------------|-----------------|----------------|
|                | <i>Pounds.</i> | <i>Pounds.</i>  | <i>Pounds.</i> |                     | <i>Pounds.</i> | <i>Pounds.</i>  | <i>Pounds.</i> |
| Wheat.....     | 8.8            | 67.5            | 1.5            | Wheat bran.....     | 11.9           | 42.0            | 2.5            |
| Oats.....      | 8.8            | 49.2            | 4.3            | Wheat middlings..   | 13.0           | 45.7            | 4.5            |
| Corn.....      | 7.8            | 66.8            | 4.3            | Beef scrap.....     | 66.2           | .....           | 13.4           |
| Barley.....    | 8.4            | 65.3            | 1.6            | Cottonseed meal.... | 37.6           | 21.4            | 9.6            |
| Corn meal..... | 6.1            | 64.3            | 3.5            | Fish meal.....      | 60.5           | .....           | 14.6           |

TABLE 13.—*Digestible nutrients in 100 pounds of feed consumed.*

| Pen. | Year. | Crude<br>protein. | Carbohy-<br>drates. | Fat.           | Nutri-<br>tive<br>ratio. | Pen. | Year. | Crude<br>protein. | Carbohy-<br>drates. | Fat.           | Nutri-<br>tive<br>ratio. |         |
|------|-------|-------------------|---------------------|----------------|--------------------------|------|-------|-------------------|---------------------|----------------|--------------------------|---------|
|      |       | <i>Pounds.</i>    | <i>Pounds.</i>      | <i>Pounds.</i> |                          |      |       | <i>Pounds.</i>    | <i>Pounds.</i>      | <i>Pounds.</i> |                          |         |
| 1    | 1913  | 14.1              | 53.1                | 4.3            | 1 : 4.5                  | 6    | 1913  | 13.4              | 56.4                | 3.9            | 1 : 4.8                  |         |
|      | 1914  | 15.4              | 51.0                | 4.5            | 1 : 4.0                  |      | 1914  | 13.1              | 56.0                | 3.9            | 1 : 4.9                  |         |
|      | 1915  | 17.1              | 48.3                | 4.8            | 1 : 3.4                  |      | 1915  | 11.2              | 57.8                | 3.6            | 1 : 5.9                  |         |
| 2    | 1913  | 12.1              | 60.1                | 3.6            | 1 : 5.6                  | 7    | 1914  | 13.9              | 55.0                | 4.4            | 1 : 4.7                  |         |
|      | 1914  | 15.0              | 64.3                | 4.2            | 1 : 4.3                  |      | 1915  | 10.6              | 58.9                | 4.0            | 1 : 6.4                  |         |
|      | 1915  | 16.8              | 51.5                | 4.5            | 1 : 3.7                  | 8    | 1914  | 14.4              | 54.6                | 4.5            | 1 : 4.5                  |         |
| 3    | 1913  | 12.1              | 56.6                | 4.1            | 1 : 5.5                  |      | 1915  | 15.1              | 53.7                | 4.6            | 1 : 4.2                  |         |
|      | 1914  | 12.9              | 55.8                | 4.3            | 1 : 5.1                  | 9    | 1914  | 8.5               | 58.4                | 3.4            | 1 : 7.7                  |         |
|      | 1915  | 9.8               | 59.3                | 3.8            | 1 : 6.9                  |      | 1915  | 8.8               | 57.6                | 3.3            | 1 : 7.4                  |         |
| 4    | 1913  | 13.2              | 55.9                | 4.3            | 1 : 5.0                  | 10   | 1915  | 12.6              | 53.1                | 4.1            | 1 : 4.9                  |         |
|      | 1914  | 13.5              | 55.3                | 4.4            | 1 : 4.8                  |      | 11    | 1915              | 13.5                | 52.1           | 4.3                      | 1 : 4.6 |
|      | 1915  | 8.9               | 60.7                | 3.7            | 1 : 7.7                  |      | 12    | 1915              | 15.6                | 53.2           | 4.7                      | 1 : 4.1 |
| 5    | 1913  | 12.5              | 56.0                | 4.2            | 1 : 5.2                  | 13   | 1915  | 14.0              | 52.2                | 4.5            | 1 : 4.5                  |         |
|      | 1914  | 13.8              | 54.4                | 4.4            | 1 : 4.7                  | 14   | 1915  | 15.1              | 51.4                | 4.5            | 1 : 4.1                  |         |
|      | 1915  | 14.3              | 53.8                | 4.5            | 1 : 4.5                  | 15   | 1915  | 13.2              | 51.9                | 4.2            | 1 : 4.6                  |         |
|      |       |                   |                     |                |                          | 16   | 1915  | 12.0              | 55.1                | 4.0            | 1 : 5.4                  |         |



Digestible protein, energy values, and total dry matter of the feedstuffs, as given in Department of Agriculture Bulletin No. 459, are shown in Table 14. These values are those worked out for farm animals; no figures of this kind are available in poultry feeding. Detailed figures showing the energy values of the rations used are given in Table 15, based on the assumption that these figures apply more or less accurately to poultry.

TABLE 14.—Average dry matter, digestible true protein, and net energy values in 100 pounds of various poultry feeds.

| Feed.          | Dry matter.    | Digestible protein. | Net energy.                | Feed.               | Dry matter.    | Digestible protein. | Net energy.                |
|----------------|----------------|---------------------|----------------------------|---------------------|----------------|---------------------|----------------------------|
|                | <i>Pounds.</i> | <i>Pounds.</i>      | <i>Therms.<sup>1</sup></i> |                     | <i>Pounds.</i> | <i>Pounds.</i>      | <i>Therms.<sup>1</sup></i> |
| Wheat.....     | 89.8           | 8.1                 | 91.82                      | Wheat bran.....     | 89.9           | 10.8                | 53.00                      |
| Oats.....      | 90.8           | 8.7                 | 67.56                      | Wheat middlings...  | 89.6           | 12.0                | 59.10                      |
| Corn.....      | 89.5           | 7.0                 | 89.16                      | Beef scrap.....     | 92.5           | 45.5                | 72.96                      |
| Barley.....    | 90.7           | 8.3                 | 89.94                      | Cottonseed meal.... | 92.5           | 35.4                | 93.46                      |
| Corn meal..... | 88.7           | 6.4                 | 88.75                      |                     |                |                     |                            |

<sup>1</sup> A therm is the quantity of heat required to raise the temperature of 1,000 kilograms (2,204.6 pounds) of water 1° C. It is equal to 1,000 large, or kilogram, calories.

TABLE 15.—Dry matter, digestible protein, and energy values in 100 pounds of feed consumed.

| Pen. | Year. | Dry matter.    | Digestible protein. | Net energy.    | Pen. | Year. | Dry matter.    | Digestible protein. | Net energy.    |
|------|-------|----------------|---------------------|----------------|------|-------|----------------|---------------------|----------------|
|      |       | <i>Pounds.</i> | <i>Pounds.</i>      | <i>Therms.</i> |      |       | <i>Pounds.</i> | <i>Pounds.</i>      | <i>Therms.</i> |
| 1    | 1913  | 90.0           | 11.70               | 77.77          | 7    | 1914  | 89.9           | 11.58               | 82.36          |
|      | 1914  | 90.2           | 12.66               | 76.50          |      | 1915  | 89.6           | 9.35                | 84.56          |
|      | 1915  | 90.0           | 13.86               | 74.82          | 8    | 1914  | 90.0           | 11.90               | 82.50          |
| 2    | 1913  | 89.6           | 10.17               | 85.04          |      | 1915  | 89.8           | 12.31               | 82.38          |
|      | 1914  | 89.8           | 12.22               | 81.25          | 9    | 1914  | 89.8           | 8.46                | 78.64          |
|      | 1915  | 89.8           | 13.46               | 78.57          |      | 1915  | 89.4           | 8.39                | 77.61          |
| 3    | 1913  | 89.9           | 10.33               | 81.66          | 10   | 1915  | 90.1           | 11.88               | 79.77          |
|      | 1914  | 89.8           | 10.90               | 82.16          | 11   | 1915  | 90.1           | 12.46               | 79.50          |
|      | 1915  | 89.5           | 8.88                | 83.83          |      | 1915  | 89.8           | 12.61               | 82.34          |
| 4    | 1913  | 89.7           | 11.06               | 82.39          | 14   | 1915  | 89.9           | 12.45               | 77.25          |
|      | 1914  | 89.9           | 11.26               | 82.38          |      | 1915  | 90.2           | 12.46               | 79.34          |
|      | 1915  | 89.4           | 8.24                | 84.64          | 16   | 1915  | 90.2           | 10.97               | 80.68          |
| 5    | 1913  | 89.8           | 10.66               | 81.58          |      |       |                |                     |                |
|      | 1914  | 89.8           | 11.52               | 81.26          |      |       |                |                     |                |
|      | 1915  | 89.8           | 11.78               | 81.06          |      |       |                |                     |                |
| 6    | 1913  | 90.4           | 11.31               | 82.81          |      |       |                |                     |                |
|      | 1914  | 90.3           | 11.16               | 81.77          |      |       |                |                     |                |
|      | 1915  | 90.1           | 9.91                | 81.67          |      |       |                |                     |                |

### SUMMARY.

This bulletin shows the results obtained in feeding experiments covering 3 years' work. In the third year 16 pens were under observation, containing a total of 366 laying hens.

The average egg yield for the first laying year in all pens was 131 eggs, and the highest pen average yield was 169.5 eggs. In the second year the average egg yield of all pens was 92.7 eggs, which decreased to 78.2 eggs in the third laying year.

Eggs were produced at an average cost for feed only of 10 cents a dozen during the pullet year, of 14 cents in the second year, and 19 cents in the third year.

Prices of individual grains in 1917 are from 20 to 100 per cent higher than the prices used in this bulletin, which should be carefully considered in estimating the present cost of egg production.

The average value of eggs over feed cost the first laying year was \$2.56 per hen, falling to \$1.41 the second year, and to \$0.79 the third year. The highest average value in any pen was \$3.41 (Pen 8).

The general-purpose fowls consumed annually 72 pounds of feed which cost \$1.13, while the Leghorns ate 55 pounds, which cost 87 cents.

Good results were obtained with rations both with and without oats. The use of this grain added variety to the ration without increasing the cost.

Fowls not fed any beef scrap or other animal protein laid only 90 eggs during their pullet year compared with 137 eggs from the beef-scrap pens, and 84 compared with 83 in their second year. The eggs of the no beef scrap pens cost about 2.2 cents per dozen more to produce the first laying year, but these costs were about equal during the second year. The fowls not fed beef scrap laid very poorly in winter, thus materially reducing the value of their eggs.

Cottonseed meal used in place of beef scrap as a high-protein feed in the ration produced brown or greenish spots on the yolks of the eggs, especially in warm weather, making a considerable proportion of them unfit for market. Eggs were produced more cheaply and at a considerably greater profit on the beef-scrap ration.

Fish meal at \$7 a ton less than beef scrap proved to be a good high-protein feed, which can be used to advantage to replace beef scrap. The fish meal did not in any way affect the flavor or quality of the eggs.

General-purpose fowls allowed to select their own mash constituents ate a dry mash containing about 63 per cent corn meal, 19 per cent beef scrap, 9 per cent bran, and 9 per cent middlings. Leghorns ate a mash of about 66 per cent corn meal, 26 per cent beef scrap, and 4 per cent each of bran and middlings. No better results were obtained by this method of feeding than where the ground grains were mixed together in a mash.

Good mashes, as indicated by these experiments, may be made of 66 per cent corn meal, 26 per cent beef scrap, and 4 per cent each of bran and middlings, or 2 pounds of corn meal and 1 pound each of bran, middlings, and beef scrap, with a scratch feed in each ration of equal parts by weight of cracked corn, wheat, and oats, which is fed so that the hens receive about equal parts of scratch feed and of mash.

The Leghorns on free range gave a considerably greater egg yield than those confined to a fair-sized yard. This difference was less marked in the general-purpose hens.

Sprouted oats fed as green feed to hens confined to yards cost about 10 cents per hen a year and 1 cent per dozen eggs, not including any charges for labor and equipment. The hens ate on an average in one year about 1.3 pounds of oyster shell and 0.7 of a pound of grit, which together cost about 1 cent per hen.

The Leghorns did not lay as well in the winter as the general-purpose breeds, especially during their second year, but the Leghorns produced eggs about 3 cents per dozen cheaper during their first year, 6.4 cents cheaper in their second year, and 9.8 cents cheaper in their third year than the general-purpose breeds. One pen of Leghorn pullets (Pen 8) produced eggs in their first year at a feed cost of 6.7 cents per dozen, while the value of the eggs per hen for the year was \$3.41 over cost of feed.

The average weight of a dozen eggs from the general-purpose fowls during their pullet year was 1.53 pounds, 1.60 during their second year, and 1.63 during their third laying year. The eggs from the Leghorns averaged 1.45 pounds during their pullet year, and 1.49 during their second and third years.

The egg production of the general-purpose fowls decreased 32 per cent in their second laying year. The decrease was considerably less in the Leghorns, their 2-year average egg production exceeding that of the general-purpose breeds by 19 eggs. The decrease in production from the second to the third year was only 4 per cent with the Leghorns, compared with 13 per cent in the general-purpose breeds.

The cheapest eggs are produced in the spring, during April, May, and June, while the greatest costs occur in October, November, and December. The lowest monthly feed cost of a dozen eggs in any of these experiments was 4 cents, while in some cases no eggs at all were produced during the month.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 562

Contribution from the Bureau of Plant Industry  
WM. A. TAYLOR, Chief



Washington, D. C.

PROFESSIONAL PAPER

September 15, 1917

THE CONTROL OF TOBACCO WILT IN THE FLUE-CURED DISTRICT.<sup>1</sup>

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[In cooperation with the North Carolina Agricultural Experiment Station.]

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IMPORTANCE OF THE DISEASE.

Tobacco wilt is a very serious disease in portions of the flue-cured district of Virginia and the Carolinas, the cigar-leaf district of

<sup>1</sup>This bulletin presents the results of investigations conducted jointly by the North Carolina Agricultural Experiment Station and the Bureau of Plant Industry for the purpose of working out practical methods for the control of tobacco wilt. The experiment station began studies to this end in 1903 and the work has been continued from that time. In 1910 cooperation with the Office of Tobacco Investigations, Bureau of Plant Industry, was effected, and the scope of the work was considerably extended. On behalf of the experiment station, the work has been directed successively by Dr. F. L. Stevens, Prof. H. R. Fulton, and one of the present writers. Messrs. W. G. Sackett, J. G. Hall, E. H. Cooper, R. O. Cromwell, W. C. Norton, and E. E. Stanford, assistants at the experiment station, have actively participated in the investigations.

western Florida and southern Georgia, and in several foreign countries. The disease was first brought to public attention in this country in 1903, when its occurrence in Granville County, N. C., was described in separate publications by R. E. B. McKenney (5),<sup>1</sup> of the Bureau of Plant Industry of the United States Department of Agriculture, and F. L. Stevens and W. G. Sackett (10), of the North Carolina Agricultural Experiment Station. Because of the possible existence of other tobacco wilts Stevens and Sackett designated the disease in question "Granville wilt," from the name of the county in which it was first definitely recognized. Additional information regarding the occurrence and nature of the disease is contained in a bulletin by Erwin F. Smith (7) which appeared in 1908.

It is not known when the wilt first appeared in the flue-cured district of southern Virginia and the Carolinas, but it seems to have been known to the farmers of Granville County at least as early as 1881. As a result of extensive investigations in this country and in the Dutch East Indies and Japan, it appears to have been definitely established that a wilt of tobacco which has long existed in the latter countries is identical with the Granville wilt (8).<sup>2</sup> In this country, tobacco growers in sections where the disease is known speak of it simply as tobacco wilt, and this name is retained in the present bulletin.

Since it first came under observation in Granville County, the wilt has continued to spread, and usually when a field once becomes infested subsequent crops of tobacco are increasingly attacked until a practically complete failure of the crop results. The wilt is an exceedingly destructive disease locally, and in the southern portion of Granville County it has caused the abandonment of tobacco culture on many farms. The disease has been most destructive in the region which enjoys the reputation of producing the finest quality of flue-cured tobacco grown in the country, and the aggregate loss to farmers is very large, although difficult to estimate accurately. The loss is serious every year, although varying considerably, depending on seasonal conditions. The plants are killed outright and a loss of 25 to 40 per cent is not unusual, while on many fields the crop is practically a total loss. Should the disease become destructive throughout the flue-cured district it would practically stop the production of this type of tobacco, the annual value of which is 30 million dollars.

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<sup>1</sup> Serial numbers in parentheses refer to "Literature cited," page 20.

<sup>2</sup> The disease in Sumatra appears to have been first studied by Janse (4) in 1892 and later by Van Breda de Haan (1) and Honing (2), who spoke of it as a "slime sickness." According to Uyeda (11) the disease is known in Japan as stem-rot, black-leg, and wilt disease and was mentioned in a book on tobacco culture published in 1881.

## SYMPTOMS OF TOBACCO WILT.

The disease affects the entire plant, leaves, stem, and roots, in a characteristic manner. It may attack plants in any stage of development, but usually symptoms first appear two to four weeks after transplanting. During the period of rapid growth which follows as soon as the tobacco plants have become established after transplanting, the number of wilted plants increases rapidly, reaching the maximum at about the usual time for topping. Under certain conditions there are exceptions to this progressive increase of wilt.

### LEAVES.

The first decided indication of the presence of wilt is the drooping of one or more leaves of the plant. This wilting usually comes on gradually, requiring several days to become prominent, and growers familiar with the disease are often able to detect the first symptoms of wilting a day or two before the layman would observe anything unusual about the plant. Affected leaves also may be somewhat distorted and wrinkled. At first there is no discoloration, but the leaves soon become pale green, especially between the larger veins, and then the leaf gradually turns yellow. Meanwhile the midrib and the veins have become limp and droop in a characteristic, umbrellalike manner, which persists even after the leaves and the stalk become brown and crisp. In some cases the leaves on one side of the plant wilt first, and sometimes only half the leaf is affected at first.

### STALK.

In the early stages of wilt, if the tobacco stalk is cut across with a knife the woody portion shows a yellowish discoloration, which becomes brownish or black as the disease progresses, especially in the lower part of the stalk. By stripping off the bark the discoloration appears as longitudinal streaks. In the advanced stages the pith also becomes affected. The inner bark also decays, and as the wet rot extends outward dry, blackened areas appear on the surface of the stalk. Pressure on discolored stalks will force out from the cut ends an opaque, dirty white ooze, very different in appearance from the normal cell sap.

### ROOTS.

The organism causing the disease enters the plant through the roots, so that by the time the leaves begin to wilt the roots will show more or less decay. When cut across with a knife the affected roots in the earlier stages will show a dark discoloration in the woody por-



tion lying near the bark. This discoloration appears as longitudinal streaks in this portion of the root, just as it does in the corresponding part of the stalk. In the early stages of the disease only a few of the roots are attacked, but eventually the whole root system is involved.

There are other diseases of tobacco involving decay of the stalk, especially the so-called sore-shin, or sore-shank, which have been mistaken for the wilt, but the presence of a characteristic slimy ooze when the stalk is cut and the black streaks in the woody portion are usually sufficient to distinguish the wilt from other diseases. In typical sore-shin, moreover, the stalk rots near the base, causing the plant to topple over.

#### CAUSE OF THE DISEASE AND ITS PRESENT DISTRIBUTION.

Tobacco wilt is caused by *Bacterium solanacearum* E. F. S. This is a well-known organism, first studied by Dr. Erwin F. Smith (6), which causes a destructive rot of the tomato and Irish potato and attacks many other plants besides these and tobacco. In infected tobacco plants the bacteria soon become so abundant in the woody vessels that these become plugged, thus cutting off the water supply of the leaves, thereby causing them to wilt. If only the vessels on one side of the plant first become clogged, then only the leaves on that side of the plant will at first wilt. Naturally, with the water supply cut off, no further development of the leaves is possible and the plant must soon die. Various theories as to the cause of tobacco wilt have been put forward by farmers, and it has been believed by many that the fertilizers used on the tobacco crop have been responsible in some way for the appearance of the disease. It is true that fertilizers, cultural methods, weather conditions, and the like may influence the extent of progress of the disease, but, as already indicated, there is no doubt whatever that the disease is due to a specific parasite.

As has been stated, tobacco wilt, though designated by other names, has long been known in Sumatra and Java and in Japan. In this country it was first found in Granville County, N. C., but about 10 years ago it made its appearance in the cigar-tobacco district of Gadsden County, Fla., and Decatur County, Ga., probably having been introduced there through tobacco stems used as fertilizer which came from the wilt district of North Carolina. For a number of years the disease in Granville County was confined to the southern portion of the county lying between the Tar and Neuse Rivers. This happens to be the section enjoying the reputation of producing the finest flue-cured tobacco grown in this country. Within this area

the spread of the disease has been rather rapid, so that now but few farms are free from it. The disease has not spread so rapidly outside of this section, although it has long since crossed the above-mentioned rivers. It has reached the adjoining counties of Vance, Durham, Wake, and Franklin and also has been found in Ashe, Guilford, Greene, Chatham, Davidson, and Yadkin Counties. It is quite possible that tobacco wilt also exists in other sections of the flue-cured district. Although the outward spread of this wilt is not particularly rapid, its progress is none the less certain, and once established it is exceedingly persistent and exceptionally destructive.

### SUSCEPTIBILITY OF SPECIES AND VARIETIES OF TOBACCO TO THE WILT.

In dealing with the problem of control the first line of attack was the search for resistant varieties of tobacco. The simplest solution, of course, would be the discovery of a resistant type in the standard native varieties used in growing flue-cured tobacco. Failing in this, the next step would be to find a resistant type among the numerous varieties used in growing other classes or kinds of tobacco which are produced in this and foreign countries. If such a resistant type could be found, it could be crossed with the native flue-cured varieties with a fair prospect of obtaining a new variety combining the resistant properties of the foreign with the commercial qualities of the native varieties. For several years past extensive tests have been made with nearly all available varieties, including many from foreign countries, but while some varieties have been found to be less susceptible than others the resistance was not sufficient to meet practical requirements. Although the final results were negative, it seems desirable to summarize briefly the work along these lines. In making the tests the general plan has been to grow the different varieties in rows side by side on soil known to be badly diseased, including occasional rows of a standard native variety, so as to measure the relative degree to which the different parts of the field were diseased. Records of the number of healthy plants and the number dead or wilted were made at intervals during the growing period, the last records being taken when the plants had reached maturity.

In the first tests, made in 1904, 62 varieties or types known by distinctive varietal names were used.<sup>1</sup> These included some 25 subvarieties or strains of Oronoco, several of the Pryors, White Burley, Maryland, the Broadleaf, or Seedleaf, and Havana Seed types of the northern cigar-leaf districts and domestic and imported

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<sup>1</sup> For further details of the tests, see Stevens, F. L. (9).

Cuban, Turkish, and Sumatra tobaccos. Practically all domestic types of tobacco were represented, but none showed a high degree of resistance, 70 to 90 per cent of the plants succumbing to the disease. Work with local flue-cured varieties has been continued up to the present. Each year seed from plants which had survived in the previous year's test has been planted, but no progress has been made in developing a resistant strain. In the tests with foreign varieties, including varieties from South America, Mexico, Cuba, Sumatra, Turkey in Asia, Turkey in Europe, Italy, and Russia, it was found that the Sumatra, a Turkish variety from Cavala in Macedonia, and a variety from Italy designated by Comes as *Nicotiana tabacum fruticosa* showed considerable resistance to the wilt, and selections from these were grown for several years. The Sumatra and Turkish were crossed also with the local flue-cured type in an effort to develop a highly resistant commercial variety. The most striking feature of these experiments was the fact that the resistance of the above-mentioned varieties depends largely on seasonal conditions. Under conditions tending to produce slow growth, particularly dry weather, these varieties have shown a relatively high degree of resistance, and in some years less than 10 per cent of the plants died. Under conditions favoring rapid growth, especially periods of wet weather, on the other hand, nearly all plants died. No highly resistant types were obtained from any of the hybrids.

A type of imported Cuban tobacco showed a resistance of 12 per cent in 1911, 96 per cent in 1912, 78 per cent in 1913, and 46 per cent in 1914, variations apparently due to seasonal conditions. Taking the tests as a whole, the Sumatra variety has shown the highest resistance of all varieties. In this connection it should be stated that Honing (2), working along the same lines in Sumatra, tested varieties from various parts of the world, including 30 or more American varieties, and found none more resistant than the native Deli (Sumatra). The Halladay, a type developed in Connecticut from a cross of Sumatra on Connecticut Havana, also has shown considerable resistance in the present tests.

Since the investigations failed to show sufficient resistance in any of the varieties of tobacco belonging to the ordinary species grown in America (*Nicotiana tabacum*), it seemed worth while to test various other species, wild and cultivated. Tests were made with several varieties of *Nicotiana rustica* from Italy, Russia, China, and elsewhere, but all of these were found to be very susceptible. Other species tried were *longiflora*, *glauca*, *glutinosa*, *longsdorffii*, *silvestris*, *affinis*, and *sanderac* (hybrid), none of which showed higher resistance than the ordinary tobaccos.



## RELATION OF THE PHYSICAL AND CHEMICAL PROPERTIES OF THE SOIL TO THE WILT.

The second line of attack in searching for a practical method of controlling the wilt was to determine whether the soil could be treated by chemical or physical methods which would destroy the organism causing the trouble or weaken its activity. In 1904 a series of field plats on infested soil at Creedmoor, N. C., was given various chemical treatments before being set to tobacco. Heavy applications of powerful disinfectants, including several salts of copper, formalin, corrosive sublimate, permanganate of potash, carbolic acid, iron sulphate, and sulphur, were tried. Strong acids and alkalis and excessive applications of potash, nitrogen, and phosphoric acid also were tested. None of the treatments gave any promise of success in practical tobacco culture. In 1910 another series of field tests with chemicals was made on a diseased field near Creedmoor, including a more extensive study of the effect of acid and alkaline conditions on the disease. The effects on the wilt of soluble forms of calcium, magnesium, silicon, aluminum, iron, and manganese were tested, but without results, these tests being based on the assumption that the wilt is not to be feared in soils containing large amounts of clay. Various fertilizer treatments were tried, only materials tending to produce alkaline conditions being used on some plats, while on others only substances favoring an acid reaction were employed. For example, one plat received per acre 200 pounds of carbonate of potash, 600 pounds of basic slag, 250 pounds of nitrate of soda, 500 pounds of cottonseed meal, and 2,000 pounds of burned lime, while another received equivalent amounts of sulphate of potash, acid phosphate, ammonium sulphate, and acid sodium sulphate. None of these treatments produced any decided effect on the amount of wilt.

In the following year, in order better to control the experimental conditions, a large number of glazed-tile cylinders  $2\frac{1}{2}$  feet long and 2 feet in diameter were set in the ground so as to leave about 3 inches projecting above the ground level. The cylinders were installed at West Raleigh and at Creedmoor. The pots were filled to a depth of about a foot with bottom earth taken from the holes in which the pots were placed, after which about 8 inches of subsoil and 8 inches of topsoil from a diseased tobacco field at Creedmoor were added. All tests were made in duplicate and each cylinder contained four plants. In continuation of previous work, tests were made with mixtures of varying proportions of sandy and clay soils; with ordinary wilt soil, to which were added separately the chief chemical constituents of clay; with plants grown from seeds without transplant-

ing, so as to avoid breaking the roots; with acid reagents and alkaline reagents; and with various chemical disinfectants. Considerable difficulty was experienced in maintaining the infection in the cylinders, because of their becoming excessively dry or from some other unfavorable condition, so the results were rather inconstant and uncertain. The results of tests covering three years, mixtures of sandy and clay soils being used, seemed to indicate that the wilt organism is not very active in clayey soils, but none of the chemical constituents of clays applied singly to sandy soils appeared to have any decided action on the organism. A rather extensive series of tests was made with acids and alkalis. For the former sulphuric acid, acid potassium sulphate, and nitric acid were used, and for the latter quicklime, calcium carbonate, potassium carbonate, sodium silicate, and sodium carbonate were employed. In most cases at least two different rates of application were made. The results of tests covering three years indicate in general that alkalis are favorable to the wilt organism, while acids retard its development, but the results were not very constant and failed to furnish any basis for a practical remedy. Details of the tests are shown in part in Table I. Each cylinder should have contained four plants, but it will be noted that the stand was poor, due largely to the toxic action of the chemicals applied to the soil.

TABLE I.—*Tests of tobacco plants grown in cylinders containing soil treated with acids and with alkalis at West Raleigh and Creedmoor, N. C., in 1913 and 1914.*

| Cylinder No. and location of test. <sup>1</sup> | Soil treatment.                                        | 1913.—Number of plants. |          | 1914.—Number of plants. |          |
|-------------------------------------------------|--------------------------------------------------------|-------------------------|----------|-------------------------|----------|
|                                                 |                                                        | Wilted.                 | Healthy. | Wilted.                 | Healthy. |
| 11 and 18.....                                  | Acid potassium sulphate, 17 grams.....                 | None.                   | .....    | None.                   | 3        |
| 11 and 13 (Creedmoor).....                      | Acid potassium sulphate, 85 grams.....                 | 2                       | 6        | .....                   | .....    |
| 35 and 42.....                                  | Sulphuric acid, 1 ounce in 6 quarts of water           | 2                       | .....    | .....                   | .....    |
| 46.....                                         | Sulphuric acid, 2 ounces in 6 quarts of water.         | None.                   | .....    | None.                   | 3        |
| 38 and 43.....                                  | Nitric acid, <sup>2</sup> 1 ounce in 6 quarts of water | 4                       | .....    | None.                   | 5        |
| 14 and 21.....                                  | Lime carbonate, 600 grams.....                         | 1                       | .....    | 1                       | 4        |
| 4 (Creedmoor).....                              | Quicklime, 300 grams.....                              | 3                       | 1        | .....                   | .....    |
| 10 (Creedmoor), 12 (Creedmoor).....             | Potassium carbonate, 70 grams.....                     | 9                       | .....    | .....                   | .....    |
| 17 and 24.....                                  | Sodium carbonate, 300 grams.....                       | 4                       | .....    | .....                   | .....    |
| 12 and 19.....                                  | Sodium silicate, 17 grams.....                         | 1                       | .....    | 2                       | 2        |
| 15 and 22.....                                  |                                                        |                         |          |                         |          |

<sup>1</sup> Tests located at West Raleigh, except as otherwise stated.

<sup>2</sup> Cylinder No. 38 received 4 ounces of nitric acid and cylinder No. 43 received no acid in 1914.

In the cylinder tests with disinfectants, use was made of formalin, potassium permanganate, chlorid of lime, atomic or superfine sulphur,  $\beta$ -naphthol, Bordeaux mixture, and a number of proprietary preparations, mostly coal-tar products, many of them in varying rates of application. No decidedly beneficial results were obtained.

During the four years, 1911 to 1914, inclusive, field plats at Creedmoor, N. C., consisting of single rows, were used in trials with disinfectants. The usual fertilizing and cultural methods were followed alike on all plats. The results for 1911 and 1912 are shown in part in Table II. The permanganate of potash and chlorid of lime were applied in the same quantities and in double the quantities recommended by Honing in Sumatra, the weaker solutions consisting of 125 grams of the chemical in 25 gallons of water. The solutions were poured into the holes in which the plants were to be set 24 hours before transplanting.

TABLE II.—*Field experiments with tobacco plants, showing the effects of soil disinfectants at Creedmoor, N. C., in 1911 and 1912.*

| Year of tests and chemicals used.     | Method and rate of application.     | Number of plants. |          | Percentage of wilt. |
|---------------------------------------|-------------------------------------|-------------------|----------|---------------------|
|                                       |                                     | Wilted.           | Healthy. |                     |
| Tests in 1911 (condition on Aug. 12): |                                     |                   |          |                     |
| Check.....                            |                                     | 30                | 1        | 96.8                |
| Potassium permanganate.....           | Weak solution, 2 quarts per hill.   | 39                | 4        | 90.7                |
| Check.....                            |                                     | 29                | 2        | 93.5                |
| Chlorid of lime.....                  | Weak solution, 2 quarts per hill.   | 27                | 3        | 90                  |
| Check.....                            |                                     | 23                | 3        | 88.5                |
| Potassium permanganate.....           | Strong solution, 2 quarts per hill. | 32                | 2        | 94.1                |
| Check.....                            |                                     | 25                | 0        | 100                 |
| Chlorid of lime.....                  | Strong solution, 2 quarts per hill. | 17                | 1        | 94.4                |
| Tests in 1912 (condition on Aug. 5):  |                                     |                   |          |                     |
| Check.....                            |                                     | 5                 | 37       | 11.9                |
| Toluol.....                           | 50 gallons per acre.....            | 27                | 35       | 43.5                |
| Check.....                            |                                     | 38                | 17       | 69.1                |
| Toluol.....                           | 25 gallons per acre.....            | 39                | 22       | 63.9                |
| Check.....                            |                                     | 35                | 19       | 64.8                |
| Toluol.....                           | 100 gallons per acre.....           | 40                | 18       | 69                  |
| Check.....                            |                                     | 40                | 12       | 76.9                |
| Check.....                            |                                     | 26                | 19       | 57.8                |

In 1913 and 1914 the experiments were continued along the same lines, with the use of formalin, sulphuric acid, naphthol, carbolic acid, Bordeaux mixture, atomic sulphur, lime sulphur, coal tar, pine tar, and several proprietary disinfectants. In these tests more than a score of germicides and other chemicals were applied in various quantities and in various ways. Since the same plat was used each year, the cumulative effect of the chemicals was detrimental to the growth of the tobacco. Here, as in the cylinders, it was difficult to secure a good stand of plants. In general, there have been no consistent differences in the percentages of wilt in the treated and the untreated rows. The results are confirmatory of the cylinder tests and do not promise success in wilt control through the use of chemicals. In 1915 certain materials supposed to contain radium, including Banque du Radium, carnotite, and a radioactive earth, were tried in several differing quantities at Creedmoor, but without any definite results.



It should be added finally that in view of the theory entertained by some that lack of drainage or aeration in the soil is a cause of wilt, experiments were made on the effects of deep plowing and subsoiling, but the results were entirely negative. Dynamiting the soil according to methods recommended was tried, with a view to destroying any hardpan or impervious layer beneath the topsoil, but no beneficial action could be noted.

#### CROP ROTATION AS A BASIS FOR THE CONTROL OF THE WILT.

It has been seen that so far as known all species and varieties of tobacco, both wild and cultivated, are readily destroyed by the wilt, and it is well known that other plants belonging to the same family are seriously attacked. Obviously none of these plants should be grown on tobacco land affected with wilt. The parasite, however, is by no means limited to solanaceous plants, and is now known to attack members of no less than nine distinct families of the higher plants, namely, (1) Solanaceæ (including tobacco, Irish potato, pepper, eggplant, jimson weed, etc.), (2) Leguminosæ (including the peanut), (3) Balsaminaceæ, (4) Compositæ (including the common ragweed), (5) Euphorbiaceæ, (6) Pedaliaceæ, (7) Tropæolaceæ, (8) Urticaceæ, and (9) Verbenaceæ. It is probable that further search will show that still other plants are attacked by this organism. Outside of the Solanaceæ the peanut and the ordinary ragweed are of special importance in the flue-cured district. In parts of the district peanuts are an important money crop and the ragweed (*Ambrosia artemisiæfolia*) is extremely common on tobacco lands throughout the district. Peanuts must be avoided and the ragweed kept down if rotation of crops is to be effective in controlling the wilt.

#### CROP-ROTATION EXPERIMENTS AT CREEDMOOR, N. C.

Beginning with 1911, experiments on the effectiveness of crop rotation for the control of tobacco wilt have been conducted on a tobacco field near Creedmoor, N. C., on which tobacco was practically a total failure in 1910. The soil in this field is the Granville coarse sandy loam and is rather uniform throughout except for a gall spot of several square yards on the plat designated "F" in figure 1. The plats slope away gently on either side of the turn row, which extends through the center of the field. The drainage is good on all plats except for small areas on the southern edge of plat 1 and on the northern edge of plat 4, and there is but little chance for surface drainage from one plat to adjoining ones.

In these experiments the rotation and cropping systems included nearly all of the more important crops adapted to the section, namely,



FIG. 1.—Plan of the experiment field at Creedmoor, N. C., showing details of the cropping system on each plat. Plats B, C, D, E, and F were planted to tobacco in 1916.

tobacco, corn, cotton, peanuts, wheat, sweet potatoes, cowpeas, mixed clovers, and grasses. Two different types of cropping were followed. In the first type a single crop or group of crops was grown continuously on the same plat. Thus, corn was grown continuously on a quarter-acre plat for five years, with crimson clover as a winter cover crop. In the same way, peanuts and sweet potatoes were each grown continuously on separate plats for five years, in each case with rye as a winter cover crop. Wheat, followed by cowpeas cut for hay, also was grown continuously on one plat. On one plat a mixture of mammoth or sapling clover, redtop, orchard grass, and tall meadow oat-grass was grown each year, the plat having been reseeded in 1913. A plat cropped continuously to cotton was started two years later and thus far has run only three years. For comparison, tobacco was grown each year on one plat, with rye and crimson clover as a winter crop. In 1916 tobacco was grown on all plats to determine the effects of the other crops on the wilt. There were two objects in the continuous cropping to the same crop plants each year. In the first place it was not certain at the outset which of the crops are immune to the wilt, and, secondly, it was desired to determine by direct test the comparative values of the different crops in reducing the amount of wilt. This plan was fully justified by later development, for it was soon found that peanuts are quite susceptible to the disease, while, on the other hand, the remaining crops proved to be about equally effective in reducing the injury from the wilt, thus indicating that they are immune.

In the second type of cropping, a system of rotation including corn, wheat and cowpeas, red clover and grass, and tobacco was followed on a series of plats. In this series it was arranged that after

the first three years half of one of the plats would come into tobacco each year, while the other half would be kept in other crops for another series of years. This arrangement served to furnish light as to the number of years of cropping to immune crops that is required to bring the wilt under control. The general arrangement of the various plats and the system of cropping on each are shown in detail in figure 1. Cotton was not originally included in the tests, and the intention was to use rotation plat 1 for other purposes; but beginning with 1913 half of this plat was cropped to cotton each year and the other half used as a check plat, being cropped to tobacco every year. After it was observed in 1912 that the peanuts on plat C were seriously affected with wilt, a portion of this plat was used in succeeding seasons for making certain tests on the susceptibility to wilt of varieties of tomatoes. The acre plat shown in the figure was used for the tobacco variety tests already discussed. A line of tile cylinders used in the tests with chemicals and disinfectants occupied the eastern edge of plat A. The results of the cropping tests are expressed in percentages, which were arrived at by making counts of the numbers of healthy and diseased plants on each plat at the time of maturity. These results are brought together in Table III.

TABLE III.—*Results of 5-year cropping and rotation tests for the control of tobacco wilt at Creedmoor, N. C., in 1916.*

| Designation of plat.                                    | Number of plants. |         | Percent-<br>age of<br>wilt. |
|---------------------------------------------------------|-------------------|---------|-----------------------------|
|                                                         | Healthy.          | Wilted. |                             |
| Plat B (sweet potatoes continuously).....               | 927               | 249     | 21.2                        |
| Plat C (peanuts continuously) <sup>1</sup> .....        | 475               | 649     | 57.7                        |
| Plat D (corn continuously).....                         | 1,146             | 44      | 3.7                         |
| Plat E (red clover and mixed grasses continuously)..... | 1,106             | 57      | 4.9                         |
| Plat F (wheat and cowpeas continuously).....            | 1,010             | 65      | 6                           |
| Rotation plat 4-A.....                                  | 871               | 107     | 10.9                        |
| Plat 1-B (tobacco continuously).....                    | 165               | 717     | 81.3                        |

<sup>1</sup> A portion of plat C was cropped to tomatoes in 1913, 1914, and 1915.

Table III shows that on plat 1-B, cropped to tobacco each year, 81 per cent of the plants showed wilt in 1916. Figure 2 gives a good idea of the extent of the wilt on this plat. A large proportion of the diseased plants on plat 4-A were found in a poorly drained corner on the northern edge. Barring this corner, there was only about 5 per cent of wilt on this plat, which had been rotated in corn, wheat, cowpeas, grass, and clover for five years. It will be noted also that on plats D, E, and F, which had been cropped to corn, clover and grass, and wheat and cowpeas, respectively, for five years, there was only 4 to 6 per cent of wilt, so that the loss was





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FIG. 2.—A field showing the results of continuous tobacco cropping, Creedmoor, N. C. Tobacco was grown on this plat each year from 1911 to 1916, inclusive. Fully 80 per cent of the plants showed wilt on July 27, 1916. (Plat 1-B.)

negligible. The effectiveness of grass and clover and of corn in reducing the injury from wilt is shown in figures 3 and 4, respectively. It should be noted, however, that the tobacco made a much better growth after grass and clover than after corn. On plat C, one portion of which had been cropped to peanuts and the other to tomatoes, 58 per cent of the plants were affected. The portion of the plat on which tomatoes had been grown showed about 20 per cent more wilt than the portion cropped to peanuts. Figure 5 clearly shows the marked injury from wilt on this plat. The tobacco was mature and ready for harvesting by July 27, and on that date there was only 5 per cent of wilt on plat B, which had been cropped to sweet potatoes continuously for five years. The tobacco was allowed to stand, however, and on August 10 symptoms of wilt were shown by 21 per cent of the plants, while no such marked increase occurred in the other plats. A similar condition was noted on plat 1-B in 1915, for on August 3 there was only 3 per cent of wilt, while on August 11 there was 23 per cent. The normal, gradual progress of the wilt in a tobacco field is shown in Table IV, which gives the counts on the plats made from June 29 to August 10, 1916. No wilted plants were observed a week prior to June 29.

TABLE IV.—*Rate of wilting of tobacco in plats at Creedmoor, N. C., in 1916.*

| No. of plat.   | Number of plants wilted. |         |         |         |         |         |          |          |          |
|----------------|--------------------------|---------|---------|---------|---------|---------|----------|----------|----------|
|                | June 29.                 | July 1. | July 5. | July 6. | July 7. | July 8. | July 13. | July 27. | Aug. 10. |
| Plat A. ....   | 62                       | 83      | 183     | 209     | 232     | 246     | 320      | 453      | 568      |
| Plat B. ....   | 5                        | 8       | 15      | 17      | -----   | 18      | 25       | 62       | 249      |
| Plat C. ....   | 69                       | 95      | 141     | 155     | 187     | 209     | 245      | 414      | 649      |
| Plat D. ....   | 7                        | 10      | 13      | 18      | -----   | 19      | 23       | 44       | -----    |
| Plat E. ....   | 7                        | 9       | 13      | 18      | -----   | 22      | 24       | 57       | -----    |
| Plat F. ....   | 2                        | 5       | 9       | 12      | -----   | 14      | 30       | 65       | -----    |
| Plat 1-B. .... | 112                      | 157     | 249     | 324     | 371     | 396     | 534      | 660      | 717      |
| Plat 4-A. .... | 4                        | -----   | 9       | 10      | -----   | 15      | 35       | 95       | 107      |

The results of the experiments at Creedmoor extending through the past six years thus show beyond doubt that growing corn, wheat, cowpeas, clover, and mixed grasses (redtop, tall meadow oat-grass, and orchard grass), either singly or in a regular rotation, for a period of five years on badly diseased soil will reduce the loss from tobacco wilt to the point where it is almost negligible. Sweet potatoes (but not Irish potatoes) also will greatly reduce the loss from wilt, although they may be somewhat less effective for the purpose than the above-named crops. Peanuts, on the other hand, have practically no value in reducing the loss from the tobacco wilt and should not be grown on infested tobacco soils. The tests with cotton have not yet been completed, but the experience of others in the wilt section seems to leave no doubt that this crop is immune to the wilt and is to be classed with corn, wheat, and grass in this respect.



FIG. 3.—Tobacco growing after grass and clover, Creedmoor, N. C. This plat was in grass and clover for five years, 1911 to 1915, inclusive. Only 4½ per cent of the plants showed wilt on July 27, 1916. (Plat E.)





FIG. 4.—Tobacco growing after corn, Creedmoor, N. C. This plot was cropped to corn for five years, 1911 to 1915, inclusive, with crimson clover as a winter cover crop. Less than 3 per cent of the plants showed wilt on July 27, 1916, but it should be noted that the tobacco is decidedly smaller in size than that after grass and clover (plat E). (Plat D.)

Another important lesson from the experiments is that, other things being equal, injury from wilt is likely to be much greater on poorly drained spots; hence, crop rotation may be less effective under these conditions.

#### LENGTH OF ROTATION REQUIRED TO RECLAIM INFESTED SOILS.

In the preceding pages it has been demonstrated that under proper conditions the growing for a period of five years of crops not attacked by the wilt organism will make it possible, even on the worst infested fields, to produce a crop of tobacco with only a very small loss from wilt. This would mean a 6-year rotation, or 1 acre of tobacco every year for each 6 acres of tobacco land on the farm. In most cases the farmer will want to grow a larger acreage of tobacco; hence, it is important to know the shortest practicable rotation for controlling the wilt. As was explained on page 11, the rotation plats at Creedmoor were so arranged that after the third year half of one plat came into tobacco each year, and the system of cropping was that shown for rotation plats 2, 3, and 4 in figure 1 (p. 11). These experiments furnish data on the comparative effects of cropping three, four, and five years, respectively, with crops not attacked by wilt. The results are brought together in Table V.



TABLE V.—*Condition of tobacco on plats of wilt-infested land at Creedmoor, N. C., which had been planted to crops not affected by the wilt for three, four, and five years, respectively.*

| No. of plat and year of test. | Period of cropping with immune crops. | Number of plants. |         | Percentage of wilt. |                                                |
|-------------------------------|---------------------------------------|-------------------|---------|---------------------|------------------------------------------------|
|                               |                                       | Healthy.          | Wilted. | In rotation plat.   | In check plat cropped to tobacco continuously. |
| Plat 2-A, 1914 .....          | 3 years .....                         | 359               | 52      | 12.6                | 53                                             |
| Plat 3-A, 1915 .....          | 4 years .....                         | 680               | 159     | 18.9                | 72                                             |
| Plat 4-A, 1916 .....          | 5 years .....                         | 871               | 107     | 10.9                | 81                                             |

In these tests, the check plat on which tobacco was grown every year indicates that the wilt was not so destructive in 1914 as in the following two years. In the rotation plat for 1915 it should be stated that on August 3 only 3 per cent of the plants showed the wilt, while only a week later, when the final count was made, 18.9 per cent of the plants were affected. It is evident that the effectiveness of the rotation will depend to some extent on the seasonal conditions, but the growing of immune crops for four or five years probably will reduce the loss from wilt to a minimum even on very badly infested fields. On such fields it is believed that three years of such cropping will not be sufficient to bring the wilt under satisfactory control.



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FIG. 5.—Tobacco growing after peanuts and tomatoes, Creedmoor, N. C. All of this plat was cropped to peanuts in 1911 and 1912; in the three following years a portion of the plat was cropped to peanuts and a portion was planted in tomatoes. On the plat as a whole 58 per cent of the plants showed wilt on July 27, 1916. There was somewhat more wilt after tomatoes than after peanuts. (Plat C.)

although the loss would be greatly reduced, as shown by the results for 1914.

After the disease has been brought under control, it is thought that a good crop of tobacco can be grown every fourth or fifth year. Under no circumstances should a crop of tobacco be followed directly by a second one. Farmers are strongly advised against doing this, no matter how effectively the wilt may have been brought under control, for by this procedure the beneficial effects of the rotation will be largely undone and a correspondingly longer period of rotation will be required to restore the soil.

#### PRECAUTIONS TO PREVENT THE SPREAD OF THE DISEASE.

Although the rotation of crops makes it possible to grow tobacco on land infested with wilt, those farms in the wilt area that are still free from the disease command a considerable premium, because a larger acreage of tobacco can be grown on them. It is clearly to the interest of the owner to use every possible means of keeping his farm free from the tobacco wilt. Thorough burning of tobacco seed beds will destroy the wilt parasite, but the seed bed may become reinfested if diseased soil from surrounding fields, even in very small quantities, is allowed to reach the bed after it has been sterilized. The seed bed, as well as the field, also may become infested by surface drainage from infested fields. This explains the frequent observation by farmers that wilt may appear in the first crop of tobacco grown on freshly cleared lands, a fact which should serve as a warning of what may be expected if the surface drainage from neighboring wilt-infested farms is allowed to reach noninfested tobacco lands. For the above reasons tobacco growers are advised to avoid setting in fields free from infestation plants obtained from seed beds which may be infested. A half dozen infected plants may easily be the means of establishing the wilt permanently on a plantation.

There is no reason for supposing that the disease is carried over in the seed, and there is no doubt that the two principal sources from which healthy fields receive the disease are (1) soil from infested fields and (2) diseased tobacco plants, either living plants or the dead material of leaf, stem, stalk, or root. Infested soil carried on a plow borrowed from a neighbor or on the feet of an animal or of a man may serve to introduce the disease. In the process of flue curing it might be expected that the comparatively high temperatures used toward the end of the curing would be sufficient to kill the parasitic organism, but cases have been observed in Granville County in which it is highly probable that the wilt was introduced on tobacco farms through the use of stems as a fertilizer. It is not advisable to use tobacco stalks or stems from diseased fields on lands not already infested with wilt, since the curing process can not

be relied upon in all cases to sterilize these materials. Finally, tobacco growers are advised to practice rotation of crops on their tobacco lands as a means of preventing the wilt, for if the soil is exposed to infestation the disease is less likely to become established when a systematic rotation of crops is followed.

### SUMMARY.

In this country, tobacco wilt was first reported from Granville County, N. C., in 1903. Subsequent investigation has shown that the same disease, designated by other names, was already known in Sumatra and Java and in Japan. Tobacco wilt is an exceedingly destructive disease, causing the plant to die outright and frequently resulting in a practically complete failure of the crop.

The wilt produces definite symptoms in the leaves, the stalk, and the roots of the tobacco plant. The more prominent features are a characteristic umbrellalike drooping of the leaves, the presence of a yellowish to black discoloration in the woody portion of the stalk (showing as streaks when the bark is stripped off), the presence of a slimy ooze when the stalk is cut across with a knife, and a decided decay of the root system.

Tobacco wilt is caused by *Bacterium solanacearum* E. F. S., which also causes a destructive rot of the tomato and Irish potato and attacks many other plants. The organism enters the plant through the root and eventually brings about a plugging of the vessels, thus cutting off the water supply from the leaves and causing them to wilt and perish. Fertilizers, cultural methods, weather conditions, and the like may influence the extent or progress of the disease, and it has been observed that it is decidedly more destructive in relatively wet seasons.

For a time the wilt was confined to the southern portion of Granville County, N. C., but it has since spread into the adjoining counties of Vance, Durham, Wake, and Franklin and also has been found in Ashe, Guilford, Greene, Chatham, Davidson, and Yadkin Counties, N. C. The wilt also has become established in the cigar-tobacco district of western Florida and southern Georgia.

In efforts to find a tobacco resistant to wilt, numerous species and varieties, both wild and cultivated, from various parts of the world have been tested, but no species or variety has been found which is sufficiently resistant to meet practical requirements. The Sumatra and certain crosses of Sumatra with Connecticut cigar types were found to be relatively more resistant than the other forms tested.

Experiments have been carried on for several years to determine whether the wilt could be controlled by chemical or physical treatment of the soil. Various acids, alkalis, and neutral salts, including fertilizer materials, were applied to the soil by varying methods and



in varying quantities. Tests were made with a large number of germicides, including standard copper and mercury compounds, formalin, carbolic acid, and other well-known organic and inorganic germicides, in addition to numerous proprietary products. Finally, subsoiling with the plow and by the use of dynamite was tried as a possible remedy for the wilt. In none of these tests were the results sufficiently encouraging to hold out hope of controlling the disease by any of the treatments employed.

Crop rotation was the only method tested which gave satisfactory results in controlling tobacco wilt. By cropping badly infested land for five years with crops not affected by wilt the injury to the tobacco from the disease was reduced from 80 to less than 10 per cent.

The wilt germ attacks a number of plants other than tobacco, and these plants must be kept off the land if the rotation is to be effective. For this reason tomatoes, Irish potatoes, and peanuts should not be grown on tobacco lands; and since ragweed, which is a very common weed in the flue-cured district, is attacked, it is important that this weed be kept down.

The crops tested which gave satisfactory results for the practical control of the wilt are corn, wheat, rye (as a cover crop), sweet potatoes, cowpeas, grasses, red clover, and crimson clover. There is good evidence tending to show that cotton<sup>1</sup> also is not affected by tobacco wilt, and there is no reason for supposing that oats are affected.

From the tests conducted at Creedmoor, N. C., when taking into account the differences in the amount of wilt due to varying weather conditions, it appears that on badly infested land the growing of crops not attacked by wilt for four or five years will give better results than only three years of such cropping, although the 3-year period greatly reduced the amount of wilt. It is believed that on badly infested soils a crop of tobacco should not be grown oftener than once in every five years, but after the disease has been brought under control tobacco probably may be grown safely every fourth year. Under no circumstances should two crops of tobacco be grown in succession on infested soil.

To keep the wilt off farms not already infested, it is recommended that seed beds be thoroughly burned to insure complete sterilization and that care be taken not to allow surface drainage from infested farms to reach the seed bed or the tobacco land. Great caution should be used in securing plants or farming implements from farms on which the wilt is present. Tobacco stalks or stems from infested farms should not be used as a fertilizer on healthy soils. Every effort should be made to prevent infested soil or diseased plant material in any form from reaching the farm.

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<sup>1</sup> Results obtained since the text of this bulletin was written have shown that cotton is immune to the tobacco wilt.

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# UNITED STATES DEPARTMENT OF AGRICULTURE



## BULLETIN No. 563

Contribution from Bureau of Animal Industry.  
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PROFESSIONAL PAPER

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### THE DETERMINATION OF BACTERIA IN ICE CREAM.

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#### DIFFICULTY OF MAKING ACCURATE BACTERIOLOGICAL ANALYSES.

Statements have been made that the distribution of bacteria in ice cream is markedly uneven, that there is great variability in the bacterial counts of different portions of the same container, and that this variability is so great that any small sample selected for analysis will not represent the whole mass of the ice cream.

It must be remembered that the accuracy of a bacteriological analysis can never be so great as that of a chemical analysis. In making bacterial counts we are dealing with living organisms which are distributed in the material under examination. The method of analysis follows the assumption that the bacteria, as individual cells, are distributed evenly throughout the sample and that the portion removed for analysis contains a number in exact proportion to the total number in the sample. Having removed a definite part, it must then be placed in a medium suitable for plating in which the individual bacterial cells can multiply and form visible colonies. The inaccuracy of such a method must be evident at once.

We know that some bacteria are in clumps or chains, and many organisms may then develop into one colony which must be counted as a single colony. The removal of a quantity of material which will contain the same number of bacteria in suspension as another like quantity is known to be impossible. Since we are dealing with



living organisms, the bacteriological method of analysis must take into account their distribution and development into colonies on the Petri plates. In this part of the method we encounter the difficulty of separating the bacterial cells and distributing them evenly. Their development is more or less influenced by the growth of different kinds of bacteria, one of which may retard the development of those near it.

All these points are recognized by bacteriologists and are mentioned here merely to call attention to the many difficulties which arise in making accurate bacterial counts and to point out that there must be variations in the result over which the analyst has no definite control. This condition has been recognized, consequently duplicate plates are made and results reported from the average counts of both plates. The variation in bacterial counts is particularly important and must be taken into consideration when a study is made of various samples of any material containing bacteria. If these variations are not considered, mistakes are easily made in the study of the distribution of bacteria.

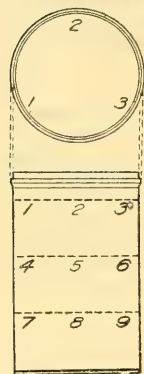


FIG. 1.—Showing location of nine samples taken from 1-gallon can of ice cream.

If the bacteria in ice cream are unevenly distributed, and a bacterial analysis of a sample does not give results which will represent the whole mass of the cream, this fact will greatly complicate any study of the bacteria in the product. Consequently, before starting any further studies on the subject it was considered advisable to carry out some experiments to throw more light on this point.

#### METHOD OF SAMPLING AND PLATING THE ICE CREAM.

Ice cream from various manufacturers was delivered in 1-gallon cans at the laboratory. As soon as received, the can of cream was removed from the tub, the ice and salt wiped off, the cover removed, and the top layer taken off with a large sterile spoon.

Three samples were taken from the topmost third of the gallon, three from the middle, and three from the bottom third, making a total of nine samples from each gallon, as shown in figure 1. Each sample contained about 30 grams and was removed with a small sterile scoop and placed in a sterile flask. After removing samples from positions 1, 2, and 3, about one-third of the ice cream was removed with a sterile spoon and three more samples taken from positions 4, 5, and 6; similarly the three remaining samples were taken from positions 7, 8, and 9.

The flasks containing the samples were then placed in water at 40° C. (104° F.) for 15 minutes in order to melt the ice cream, the

melting being hastened by frequent shaking with a circular motion. At the end of the 15-minute period each flask containing the melted ice cream was again shaken 30 times, with a circular motion, in order to mix the sample thoroughly and to shake out as much air as possible.

One cubic centimeter of melted ice cream was then removed from each flask and placed in 99 c. c. of sterile water at a temperature of 40° C. (104° F.). The water in all the dilution bottles was at a temperature of 40° C. (104° F.) in order to keep the fat in a melted condition.

The pipettes were so graduated as to deliver 1 cubic centimeter between two marks. This avoids the necessity of blowing out the pipette or immersing the end in the dilution water, and therefore eliminates the introduction of varying quantities of melted cream which adhere to the pipette.

The dilutions were made in the usual way, using 99 c. c. and 9 c. c., respectively, of sterile water. Each dilution bottle or tube was shaken 25 times, and great care was taken to measure the quantity accurately in the pipettes. Standard beef-infusion agar was used, and sufficient medium was prepared to last through the work; consequently no factor of variation was introduced by the plating medium. The plates were incubated at 30° C. (86° F.) for a period of five days, after which the duplicate plates were counted.

#### VARIATION IN THE BACTERIAL CONTENT OF COMMERCIAL ICE CREAM.

##### VARIATION IN DUPLICATE SAMPLES FROM VARIOUS PARTS OF THE SAME LOT.

In our first experiment twenty-two 1-gallon lots of ice cream were obtained from seven different manufacturers. This cream, as intended, was of different flavors, was made in different ways, and included products containing different ingredients and varying percentages of butterfat.

The complete results obtained from a study of these samples are shown in Table I, in which is recorded the percentage of fat in the ice cream from each manufacturer, also the presence or absence of gelatin, the flavor of each lot, the dilution used in plating, the number of colonies found on each of the duplicate plates, and the calculated average number of bacteria in a cubic centimeter of melted ice cream. Where there is a blank space in the number of colonies on duplicate plates no count could be made on account of "spreaders," which entirely obscured the colonies. Every count that could be obtained is included in this table of results, and no count was left out as being a "freak" result.

A study of the table shows that the bacterial counts of the nine samples from as many different positions in each gallon lot of ice cream check remarkably well with one another.

TABLE I.—*Bacteria per cubic centimeter in 198 samples from twenty-two 1-gallon lots of commercial ice cream obtained from different manufacturers.*

| Plant No. | Lot.                                | Sample No. | Flavor.      | Dilution. | Number of colonies on duplicate plates. |       | Average count per c. c. |
|-----------|-------------------------------------|------------|--------------|-----------|-----------------------------------------|-------|-------------------------|
| 1         | A (fat 9.5 per cent, gelatin +) ... | 1          | Vanilla..... | 1:1000    | 243                                     | 229   | 2,360,000               |
|           |                                     | 2          |              |           | 219                                     | 198   | 2,085,000               |
|           |                                     | 3          |              |           | 242                                     | 243   | 2,425,000               |
|           |                                     | 4          |              |           | 231                                     | 245   | 2,380,000               |
|           |                                     | 5          |              |           | 250                                     | ----- | 2,500,000               |
|           |                                     | 6          |              |           | 264                                     | 233   | 2,485,000               |
|           |                                     | 7          |              |           | 230                                     | ----- | 2,300,000               |
|           |                                     | 8          |              |           | 243                                     | 245   | 2,440,000               |
|           |                                     | 9          |              |           | 271                                     | 235   | 2,530,000               |
|           | B.....                              | 1          | Chocolate... | 1:1000    | 45                                      | 46    | 455,000                 |
|           |                                     | 2          |              |           | 40                                      | 49    | 445,000                 |
|           |                                     | 3          |              |           | 50                                      | 47    | 485,000                 |
|           |                                     | 4          |              |           | 67                                      | 40    | 535,000                 |
|           |                                     | 5          |              |           | 52                                      | 47    | 495,000                 |
|           |                                     | 6          |              |           | 60                                      | 43    | 515,000                 |
|           |                                     | 7          |              |           | 42                                      | 48    | 450,000                 |
|           |                                     | 8          |              |           | 49                                      | 45    | 470,000                 |
|           |                                     | 9          |              |           | 57                                      | 60    | 585,000                 |
|           | C.....                              | 1          | Peach.....   | 1:1000    | 146                                     | 153   | 1,495,000               |
|           |                                     | 2          |              |           | 160                                     | 150   | 1,550,000               |
|           |                                     | 3          |              |           | 137                                     | 155   | 1,460,000               |
|           |                                     | 4          |              |           | 148                                     | 145   | 1,465,000               |
|           |                                     | 5          |              |           | 140                                     | 156   | 1,480,000               |
|           |                                     | 6          |              |           | 170                                     | 151   | 1,605,000               |
|           |                                     | 7          |              |           | 153                                     | 155   | 1,540,000               |
|           |                                     | 8          |              |           | 154                                     | 148   | 1,510,000               |
|           |                                     | 9          |              |           | 154                                     | 166   | 1,600,000               |
|           | D.....                              | 1          | Vanilla..... | 1:1000    | 24                                      | 26    | 25,000                  |
|           |                                     | 2          |              |           | 23                                      | 25    | 24,000                  |
|           |                                     | 3          |              |           | 80                                      | ----- | 80,000                  |
|           |                                     | 4          |              |           | 20                                      | 32    | 26,000                  |
|           |                                     | 5          |              |           | 20                                      | 20    | 20,000                  |
|           |                                     | 6          |              |           | 30                                      | 22    | 26,000                  |
|           |                                     | 7          |              |           | 40                                      | ----- | 40,000                  |
|           |                                     | 8          |              |           | 25                                      | 26    | 25,500                  |
|           |                                     | 9          |              |           | 25                                      | 27    | 26,000                  |
|           | E.....                              | 1          | Vanilla..... | 1:1000    | 64                                      | 79    | 7,150                   |
|           |                                     | 2          |              |           | 117                                     | ----- | 11,700                  |
|           |                                     | 3          |              |           | 120                                     | 96    | 10,800                  |
|           |                                     | 4          |              |           | 109                                     | 118   | 11,350                  |
|           |                                     | 5          |              |           | 95                                      | 118   | 10,650                  |
|           |                                     | 6          |              |           | 102                                     | ----- | 10,200                  |
|           |                                     | 7          |              |           | 138                                     | 97    | 11,750                  |
|           |                                     | 8          |              |           | 77                                      | ----- | 7,700                   |
|           |                                     | 9          |              |           | 131                                     | 129   | 13,000                  |
| 2         | A.....                              | 1          | Vanilla..... | 1:10000   | 25                                      | 62    | 43,500,000              |
|           |                                     | 2          |              |           | 44                                      | 54    | 49,000,000              |
|           |                                     | 3          |              |           | 54                                      | 46    | 50,000,000              |
|           |                                     | 4          |              |           | 53                                      | 47    | 50,000,000              |
|           |                                     | 5          |              |           | 59                                      | ----- | 59,000,000              |
|           |                                     | 6          |              |           | 58                                      | 54    | 56,000,000              |
|           |                                     | 7          |              |           | 67                                      | 55    | 61,000,000              |
|           |                                     | 8          |              |           | 50                                      | 59    | 54,500,000              |
|           |                                     | 9          |              |           | 59                                      | 55    | 57,000,000              |
|           | B.....                              | 1          | Chocolate... | 1:10000   | 217                                     | 218   | 217,500,000             |
|           |                                     | 2          |              |           | 212                                     | 193   | 201,500,000             |
|           |                                     | 3          |              |           | 186                                     | ----- | 186,000,000             |
|           |                                     | 4          |              |           | 233                                     | 217   | 225,000,000             |
|           |                                     | 5          |              |           | 204                                     | 195   | 199,500,000             |
|           |                                     | 6          |              |           | 204                                     | 184   | 194,000,000             |
|           |                                     | 7          |              |           | 187                                     | 174   | 180,500,000             |
|           |                                     | 8          |              |           | 203                                     | 200   | 201,500,000             |
|           |                                     | 9          |              |           | 192                                     | 184   | 188,000,000             |



TABLE I.—*Bacteria per cubic centimeter in 198 samples from twenty-two 1-gallon lots of commercial ice cream obtained from different manufacturers—Continued.*

| Plant No. | Lot.                                | Sample No. | Flavor.      | Dilution. | Number of colonies on duplicate plates. |       | Average count per c. c. |
|-----------|-------------------------------------|------------|--------------|-----------|-----------------------------------------|-------|-------------------------|
| 2         | C (fat 9.6 per cent, gelatin +)...  | 1          | Vanilla..... | 1:100,000 | 60                                      | 64    | 62,000,000              |
|           |                                     | 2          |              |           | 63                                      | 65    | 64,000,000              |
|           |                                     | 3          |              |           | 73                                      | 62    | 67,500,000              |
|           |                                     | 4          |              |           | 70                                      | 68    | 69,000,000              |
|           |                                     | 5          |              |           | 64                                      | 70    | 67,000,000              |
|           |                                     | 6          |              |           | 73                                      | 77    | 75,000,000              |
|           |                                     | 7          |              |           | 63                                      | 57    | 60,000,000              |
|           |                                     | 8          |              |           | 63                                      | 72    | 67,500,000              |
|           |                                     | 9          |              |           | 57                                      | 72    | 64,500,000              |
| 3         | A (fat 9.6 per cent, gelatin +)...  | 1          | Vanilla..... | 1:100     | 286                                     | 290   | 288,000                 |
|           |                                     | 2          |              |           | 360                                     | 254   | 307,000                 |
|           |                                     | 3          |              |           | 270                                     | 289   | 279,500                 |
|           |                                     | 4          |              |           | 250                                     | 270   | 260,000                 |
|           |                                     | 5          |              |           | 314                                     | 250   | 282,000                 |
|           |                                     | 6          |              |           | 251                                     | 252   | 251,500                 |
|           |                                     | 7          |              |           | 268                                     | 250   | 259,000                 |
|           |                                     | 8          |              |           | 311                                     | 287   | 299,000                 |
|           |                                     | 9          |              |           | 261                                     | 306   | 283,500                 |
|           | B.....                              | 1          | Peach.....   | 1:100     | 219                                     | 186   | 202,500                 |
|           |                                     | 2          |              |           | 214                                     | ..... | 214,000                 |
|           |                                     | 3          |              |           | 222                                     | 190   | 206,000                 |
|           |                                     | 4          |              |           | 192                                     | ..... | 192,000                 |
|           |                                     | 5          |              |           | 212                                     | 194   | 203,000                 |
|           |                                     | 6          |              |           | 197                                     | 200   | 198,500                 |
|           |                                     | 7          |              |           | 212                                     | 208   | 210,000                 |
|           |                                     | 8          |              |           | 231                                     | 205   | 218,000                 |
|           |                                     | 9          |              |           | 218                                     | 224   | 221,000                 |
|           | C.....                              | 1          | Chocolate... | 1:100     | 107                                     | 104   | 1,055,000               |
|           |                                     | 2          |              |           | 118                                     | 99    | 1,085,000               |
|           |                                     | 3          |              |           | 96                                      | 99    | 975,000                 |
|           |                                     | 4          |              |           | 106                                     | 96    | 1,010,000               |
|           |                                     | 5          |              |           | 108                                     | 119   | 1,135,000               |
|           |                                     | 6          |              |           | 123                                     | 124   | 1,235,000               |
|           |                                     | 7          |              |           | 102                                     | 97    | 995,000                 |
|           |                                     | 8          |              |           | 124                                     | 123   | 1,235,000               |
|           |                                     | 9          |              |           | 103                                     | 121   | 1,120,000               |
| 4         | A (fat, 22.5 per cent, gelatin-)... | 1          | Vanilla..... | 1:100,000 | 341                                     | 334   | 33,750,000              |
|           |                                     | 2          |              |           | 274                                     | 266   | 27,000,000              |
|           |                                     | 3          |              |           | 284                                     | ..... | 28,400,000              |
|           |                                     | 4          |              |           | 294                                     | 302   | 29,800,000              |
|           |                                     | 5          |              |           | 284                                     | 270   | 27,700,000              |
|           |                                     | 6          |              |           | 301                                     | 303   | 30,200,000              |
|           |                                     | 7          |              |           | 325                                     | 331   | 32,800,000              |
|           |                                     | 8          |              |           | 321                                     | 329   | 32,500,000              |
|           |                                     | 9          |              |           | 314                                     | ..... | 31,400,000              |
|           | B.....                              | 1          | Peach.....   | 1:100     | 321                                     | 310   | 31,500,000              |
|           |                                     | 2          |              |           | 270                                     | 305   | 28,750,000              |
|           |                                     | 3          |              |           | 386                                     | 372   | 37,900,000              |
|           |                                     | 4          |              |           | 278                                     | 305   | 29,150,000              |
|           |                                     | 5          |              |           | 367                                     | 356   | 36,150,000              |
|           |                                     | 6          |              |           | 354                                     | 357   | 35,550,000              |
|           |                                     | 7          |              |           | 431                                     | 466   | 44,850,000              |
|           |                                     | 8          |              |           | 470                                     | ..... | 47,000,000              |
|           |                                     | 9          |              |           | 434                                     | ..... | 43,400,000              |
|           | C.....                              | 1          | Chocolate... | 1:100     | 310                                     | 298   | 30,400,000              |
|           |                                     | 2          |              |           | 286                                     | ..... | 28,600,000              |
|           |                                     | 3          |              |           | 330                                     | ..... | 33,000,000              |
|           |                                     | 4          |              |           | 295                                     | 288   | 29,050,000              |
|           |                                     | 5          |              |           | 284                                     | 288   | 28,600,000              |
|           |                                     | 6          |              |           | 328                                     | 292   | 31,000,000              |
|           |                                     | 7          |              |           | 286                                     | 278   | 28,200,000              |
|           |                                     | 8          |              |           | 275                                     | 285   | 28,000,000              |
|           |                                     | 9          |              |           | .....                                   | ..... | .....                   |

TABLE I.—*Bacteria per cubic centimeter in 198 samples from twenty-two 1-gallon lots of commercial ice cream obtained from different manufacturers—Continued.*

| Plant No. | Lot.                               | Sample No. | Flavor.      | Dilution. | Number of colonies on duplicate plates. |       | Average count per c. c. |
|-----------|------------------------------------|------------|--------------|-----------|-----------------------------------------|-------|-------------------------|
| 5         | A (fat, 17 per cent, gelatin —)... | 1          | Vanilla..... | 1:10000   | 44                                      | ----- | 440,000                 |
|           |                                    | 2          |              |           | 45                                      | 48    | 465,000                 |
|           |                                    | 3          |              |           | 46                                      | 49    | 475,000                 |
|           |                                    | 4          |              |           | 36                                      | ----- | 360,000                 |
|           |                                    | 5          |              |           | 49                                      | ----- | 490,000                 |
|           |                                    | 6          |              |           | 35                                      | 44    | 395,000                 |
|           |                                    | 7          |              |           | 47                                      | 43    | 450,000                 |
|           |                                    | 8          |              |           | 49                                      | 41    | 450,000                 |
|           |                                    | 9          |              |           | 26                                      | 41    | 335,000                 |
|           | B.....                             | 1          | Peach.....   | 1:10000   | 44                                      | 53    | 485,000                 |
|           |                                    | 2          |              |           | 46                                      | 38    | 420,000                 |
|           |                                    | 3          |              |           | 44                                      | ----- | 440,000                 |
|           |                                    | 4          |              |           | 50                                      | ----- | 500,000                 |
|           |                                    | 5          |              |           | 48                                      | ----- | 480,000                 |
|           |                                    | 6          |              |           | 42                                      | 44    | 430,000                 |
|           |                                    | 7          |              |           | 41                                      | 46    | 435,000                 |
|           |                                    | 8          |              |           | 48                                      | ----- | 480,000                 |
|           |                                    | 9          |              |           | 41                                      | ----- | 410,000                 |
|           | C.....                             | 1          | Chocolate... | 1:100000  | 142                                     | ----- | 142,000,000             |
|           |                                    | 2          |              |           | 123                                     | ----- | 123,000,000             |
|           |                                    | 3          |              |           | 137                                     | 107   | 122,000,000             |
|           |                                    | 4          |              |           | 156                                     | 152   | 154,000,000             |
|           |                                    | 5          |              |           | 120                                     | 123   | 126,500,000             |
|           |                                    | 6          |              |           | 138                                     | 135   | 136,500,000             |
|           |                                    | 7          |              |           | 142                                     | 130   | 136,000,000             |
|           |                                    | 8          |              |           | 143                                     | 130   | 136,500,000             |
|           |                                    | 9          |              |           | 145                                     | 176   | 165,000,000             |
| 6         | A (fat, 9.2 per cent, gelatin+)... | 1          | Vanilla..... | 1:100000  | 144                                     | 178   | 16,100,000              |
|           |                                    | 2          |              |           | 128                                     | 136   | 13,200,000              |
|           |                                    | 3          |              |           | 179                                     | 161   | 17,000,000              |
|           |                                    | 4          |              |           | 200                                     | ----- | 20,000,000              |
|           |                                    | 5          |              |           | 235                                     | 190   | 21,250,000              |
|           |                                    | 6          |              |           | 152                                     | ----- | 15,200,000              |
|           |                                    | 7          |              |           | 130                                     | 133   | 13,150,000              |
|           |                                    | 8          |              |           | 270                                     | ----- | 27,000,000              |
|           |                                    | 9          |              |           | 222                                     | ----- | 22,200,000              |
|           | B.....                             | 1          | Peach.....   | 1:100000  | 102                                     | ----- | 102,000,000             |
|           |                                    | 2          |              |           | 86                                      | 108   | 97,000,000              |
|           |                                    | 3          |              |           | 109                                     | 111   | 110,000,000             |
|           |                                    | 4          |              |           | 107                                     | 107   | 107,000,000             |
|           |                                    | 5          |              |           | 111                                     | 105   | 108,000,000             |
|           |                                    | 6          |              |           | 117                                     | 115   | 115,000,000             |
|           |                                    | 7          |              |           | 117                                     | 115   | 116,000,000             |
|           |                                    | 8          |              |           | 90                                      | 108   | 99,000,000              |
|           |                                    | 9          |              |           | 103                                     | 98    | 100,500,000             |
|           | C.....                             | 1          | Chocolate... | 1:100000  | 45                                      | 43    | 44,000,000              |
|           |                                    | 2          |              |           | 41                                      | 39    | 40,000,000              |
|           |                                    | 3          |              |           | 37                                      | 48    | 42,500,000              |
|           |                                    | 4          |              |           | -----                                   | ----- | -----                   |
|           |                                    | 5          |              |           | 39                                      | 43    | 41,000,000              |
|           |                                    | 6          |              |           | 41                                      | 44    | 41,000,000              |
|           |                                    | 7          |              |           | 43                                      | 42    | 42,500,000              |
|           |                                    | 8          |              |           | 37                                      | ----- | 37,000,000              |
|           |                                    | 9          |              |           | 52                                      | 41    | 46,500,000              |
|           | D.....                             | 1          | Vanilla..... | 1:10000   | 121                                     | 102   | 1,115,000               |
|           |                                    | 2          |              |           | 114                                     | 98    | 1,060,000               |
|           |                                    | 3          |              |           | 120                                     | 125   | 1,225,000               |
|           |                                    | 4          |              |           | 126                                     | 106   | 1,160,000               |
|           |                                    | 5          |              |           | 105                                     | 113   | 1,090,000               |
|           |                                    | 6          |              |           | 87                                      | 124   | 1,055,000               |
|           |                                    | 7          |              |           | 134                                     | 149   | 1,415,000               |
|           |                                    | 8          |              |           | 122                                     | 125   | 1,235,000               |
|           |                                    | 9          |              |           | 137                                     | 137   | 1,370,000               |
| 7         | A.....                             | 1          | Chocolate... | 1:10000   | 170                                     | 176   | 1,730,000               |
|           |                                    | 2          |              |           | 161                                     | ----- | 1,610,000               |
|           |                                    | 3          |              |           | 161                                     | 183   | 1,720,000               |
|           |                                    | 4          |              |           | 179                                     | 165   | 1,720,000               |
|           |                                    | 5          |              |           | 162                                     | 192   | 1,770,000               |
|           |                                    | 6          |              |           | 174                                     | ----- | 1,740,000               |
|           |                                    | 7          |              |           | 131                                     | ----- | 1,310,000               |
|           |                                    | 8          |              |           | 184                                     | 143   | 1,635,000               |
|           |                                    | 9          |              |           | 157                                     | ----- | 1,570,000               |

The maximum and minimum bacterial count of the samples from each gallon of ice cream, together with the per cent of variation, is shown in Table II.

In the samples from Plant No. 1 there was a variation of 300 per cent among the samples from lot D, which showed a minimum count of 20,000 and a maximum of 80,000 per cubic centimeter. This case, as may be noted, is extreme and may be accounted for by the fact that the 80,000 count was obtained from one plate only, the duplicate being covered with spreaders. Reference to the complete results in Table I for this lot shows that among the other samples the colony counts were very nearly alike. A similar explanation holds for lot E from Plant No. 1, in which there was a variation of 81.81 per cent, with a maximum and minimum count of 13,000 and 7,150.

Throughout the rest of the samples the only high percentage of variation was among the samples taken from lot A, Plant No. 6, a variation of 105.32 per cent. In this case the melted cream was a thick, viscous mass, which made it difficult to measure accurately in a pipette. Special care was taken in the remaining determinations of bacteria in the ice cream from this manufacturer, with the result that the percentage of variation in bacterial counts was very low.

The general variation among the samples from each gallon of ice cream was from 20 to 30 per cent, which is decidedly low, although at first thought it may seem high.

In Reprint 295 of the Public Health Reports<sup>1</sup> it is stated that in analyzing duplicate samples of milk the general average variation in each of four laboratories ranged from about 110 to 380 per cent. Just what percentage of variation in duplicate counts is normal to the method of bacterial analysis we shall not attempt to say, but a variation of 20 per cent means only the difference between 100 and 120 colonies on a Petri plate.

The small variation in our results indicates that in the ice cream examined the bacteria were rather evenly distributed and that an analysis of one sample taken in the manner described would show for all practical purposes the bacterial content of any other sample in the 1-gallon lot.

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<sup>1</sup> Conn, H. W. Standards for determining the purity of milk.



TABLE II.—*Variation in bacterial content of 9 duplicate samples from each of twenty-two 1-gallon lots of commercial ice cream.*

| Plant No. | Lot.                        | Flavor.        | Bacteria per cubic centimeter. |             | Variation in bacterial count. |
|-----------|-----------------------------|----------------|--------------------------------|-------------|-------------------------------|
|           |                             |                | Minimum.                       | Maximum.    |                               |
| 1         | A (fat, 9.5 per cent).....  | Vanilla.....   | 2,085,000                      | 2,530,000   | <i>Per cent.</i><br>21.34     |
|           | B.....                      | Chocolate..... | 445,000                        | 585,000     | 31.46                         |
|           | C.....                      | Peach.....     | 1,460,000                      | 1,600,000   | 9.59                          |
|           | D.....                      | Vanilla.....   | 20,000                         | 80,000      | 300.00                        |
|           | E.....                      | Vanilla.....   | 7,150                          | 13,000      | 81.81                         |
| 2         | A.....                      | Vanilla.....   | 43,500,000                     | 61,000,000  | 40.23                         |
|           | B.....                      | Chocolate..... | 180,500,000                    | 225,000,000 | 24.65                         |
|           | C (fat, 9.6 per cent).....  | Vanilla.....   | 60,000,000                     | 75,000,000  | 25.00                         |
| 3         | A (fat, 9.6 per cent).....  | Vanilla.....   | 251,500                        | 307,000     | 22.31                         |
|           | B.....                      | Peach.....     | 192,000                        | 221,000     | 15.10                         |
|           | C.....                      | Chocolate..... | 975,000                        | 1,235,000   | 26.66                         |
| 4         | A (fat, 22.5 per cent)..... | Vanilla.....   | 27,000,000                     | 33,750,000  | 25.00                         |
|           | B.....                      | Peach.....     | 28,750,000                     | 47,000,000  | 63.47                         |
|           | C.....                      | Chocolate..... | 28,000,000                     | 33,000,000  | 17.85                         |
| 5         | A (fat, 17 per cent).....   | Vanilla.....   | 335,000                        | 490,000     | 46.27                         |
|           | B.....                      | Peach.....     | 410,000                        | 500,000     | 21.95                         |
|           | C.....                      | Chocolate..... | 122,000,000                    | 160,500,000 | 31.55                         |
| 6         | A (fat, 9.2 per cent).....  | Vanilla.....   | 13,150,000                     | 27,000,000  | 105.32                        |
|           | B.....                      | Peach.....     | 97,000,000                     | 116,000,000 | 19.59                         |
|           | C.....                      | Chocolate..... | 37,000,000                     | 46,500,000  | 25.67                         |
|           | D.....                      | Vanilla.....   | 1,055,000                      | 1,415,000   | 34.12                         |
| 7         | A.....                      | Chocolate...   | 1,310,000                      | 1,770,000   | 35.11                         |

## VARIATION WHEN HELD IN AN ICE-CREAM CABINET.

It was thought that there might be an uneven distribution of bacteria in ice cream held in an ice-cream cabinet where it is allowed to soften, then is repacked with ice and salt and again hardened. To determine this point, three 1-gallon lots of ice cream were purchased from three different manufacturers and held for 11 days in a commercial ice-cream cabinet, such as is used in stores.

The ice cream was packed with ice and salt once a day in the regular way. From day to day it softened and again hardened. In Table III it may be seen that even under this extreme condition the highest variation among the samples from each lot was only 37.03 per cent. In this case the lowest count was 1,080,000 and the highest 1,420,000 per cubic centimeter.

**TABLE III.**—*Variation in bacterial counts of 9 samples of ice cream taken from each of three 1-gallon lots which had been held in a cabinet for 11 days.*

| Plant No. | Sample No. | Dilution.         | Number of colonies on duplicate plates. |       | Average count per c. c. | Variation between lowest and highest counts. |
|-----------|------------|-------------------|-----------------------------------------|-------|-------------------------|----------------------------------------------|
| 1         | 1          | $\frac{1}{10000}$ | 44                                      | 48    | 46,000                  | Samples 5 and 7, 34.21 per cent.             |
|           | 2          |                   | 52                                      | 43    | 47,500                  |                                              |
|           | 3          |                   | 46                                      | ----- | 46,000                  |                                              |
|           | 4          |                   | 48                                      | ----- | 48,000                  |                                              |
|           | 5          |                   | 38                                      | ----- | 38,000                  |                                              |
|           | 6          |                   | 43                                      | 46    | 44,500                  |                                              |
|           | 7          |                   | 51                                      | ----- | 51,000                  |                                              |
|           | 8          |                   | 37                                      | 50    | 43,500                  |                                              |
|           | 9          |                   | 43                                      | ----- | 43,000                  |                                              |
| 2         | 1          | $\frac{1}{10000}$ | 108                                     | ----- | 1,080,000               | Samples 1 and 8, 37.03 per cent.             |
|           | 2          |                   | 111                                     | 125   | 1,180,000               |                                              |
|           | 3          |                   | 112                                     | ----- | 1,120,000               |                                              |
|           | 4          |                   | 142                                     | 134   | 1,380,000               |                                              |
|           | 5          |                   | 132                                     | 152   | 1,420,000               |                                              |
|           | 6          |                   | 127                                     | 113   | 1,200,000               |                                              |
|           | 7          |                   | 136                                     | 149   | 1,425,000               |                                              |
|           | 8          |                   | 130                                     | 166   | 1,480,000               |                                              |
|           | 9          |                   | 138                                     | 149   | 1,435,000               |                                              |
| 5         | 1          | $\frac{1}{10000}$ | 62                                      | 76    | 690,000                 | Samples 2 and 5, 14.73 per cent.             |
|           | 2          |                   | 64                                      | 65    | 645,000                 |                                              |
|           | 3          |                   | 76                                      | 61    | 685,000                 |                                              |
|           | 4          |                   | 65                                      | ----- | 650,000                 |                                              |
|           | 5          |                   | 74                                      | ----- | 740,000                 |                                              |
|           | 6          |                   | 65                                      | 77    | 710,000                 |                                              |
|           | 7          |                   | 66                                      | 71    | 685,000                 |                                              |
|           | 8          |                   | 66                                      | ----- | 660,000                 |                                              |
|           | 9          |                   | 70                                      | 68    | 690,000                 |                                              |

Keeping in mind the normal variation in bacterial counts, as indicated in Table II, we do not believe that the results warrant the conclusion that there is any great uneven distribution of bacteria in ice cream, even when held under the extreme conditions of this experiment.

#### VARIATION WHEN HELD IN STORAGE.

In order to determine the effect of cold storage upon the distribution of bacteria in ice cream, three 1-gallon cans were filled with ice cream from the same freezer. Of these, one was examined while fresh, one was held in cold storage in a hardening room at a plant for one month, and the third was similarly held for two months.

The results of this experiment, recorded in Table IV, show that there was no increase in the variation among the samples from each gallon lot, even after two months' storage. The samples as a whole checked remarkably well, showing nothing to indicate any marked uneven distribution of bacteria.

TABLE IV.—*Variation in the bacterial content of samples of ice cream taken from gallon lots held in cold storage.*

| Age of ice cream. | Sam-<br>ple<br>No. | Number of<br>colonies on<br>duplicate<br>plates. |       | Average<br>count<br>per c. c. | Variation between<br>lowest and highest<br>counts. |
|-------------------|--------------------|--------------------------------------------------|-------|-------------------------------|----------------------------------------------------|
| Fresh.....        | 1                  | 64                                               | 79    | 7,150                         | Samples 1 and 9,<br>81.81 per cent.                |
|                   | 2                  | 117                                              | ..... | 11,700                        |                                                    |
|                   | 3                  | 120                                              | 96    | 10,800                        |                                                    |
|                   | 4                  | 109                                              | 113   | 10,350                        |                                                    |
|                   | 5                  | 95                                               | 118   | 10,650                        |                                                    |
|                   | 6                  | 102                                              | ..... | 10,200                        |                                                    |
|                   | 7                  | 133                                              | 97    | 11,750                        |                                                    |
|                   | 8                  | 77                                               | ..... | 7,700                         |                                                    |
|                   | 9                  | 131                                              | 129   | 13,000                        |                                                    |
| One month.....    | 1                  | 118                                              | ..... | 11,800                        | Samples 7 and 8,<br>15.68 per cent.                |
|                   | 2                  | 106                                              | ..... | 10,600                        |                                                    |
|                   | 3                  | 112                                              | ..... | 11,200                        |                                                    |
|                   | 4                  | 111                                              | 117   | 11,400                        |                                                    |
|                   | 5                  | 110                                              | 112   | 11,100                        |                                                    |
|                   | 6                  | 104                                              | ..... | 10,400                        |                                                    |
|                   | 7                  | 118                                              | ..... | 11,800                        |                                                    |
|                   | 8                  | 102                                              | ..... | 10,200                        |                                                    |
|                   | 9                  | 117                                              | 106   | 11,150                        |                                                    |
| Two months.....   | 1                  | 76                                               | 77    | 7,650                         | Samples 2 and 9,<br>18.31 per cent.                |
|                   | 2                  | 66                                               | 76    | 7,100                         |                                                    |
|                   | 3                  | 76                                               | 76    | 7,600                         |                                                    |
|                   | 4                  | 92                                               | 68    | 8,000                         |                                                    |
|                   | 5                  | 79                                               | 82    | 8,050                         |                                                    |
|                   | 6                  | 73                                               | 72    | 7,250                         |                                                    |
|                   | 7                  | 70                                               | 80    | 7,500                         |                                                    |
|                   | 8                  | 75                                               | 76    | 7,500                         |                                                    |
|                   | 9                  | 76                                               | 92    | 8,400                         |                                                    |

## VARIATION IN SAMPLES TAKEN DIRECTLY FROM FREEZER.

The question of whether a sample of ice cream taken from a freezer represents in bacterial content the entire contents of the freezer is one of considerable importance. To obtain information on this point 10 series of from 6 to 10 samples were taken from the large commercial freezers in an ice-cream plant. The samples were taken in the following manner: As soon as the cream was frozen and ready to flow into the final containers for hardening, the gate was opened and about 1 pint allowed to flow out. The first sample of about 50 grams was then taken by allowing the partially frozen cream to flow into a sterile salt-mouth bottle. About 1 gallon of ice cream was then allowed to flow out and a second sample taken. The remaining samples were secured in a similar way, the last one being taken from the very last portion. All were immediately iced and taken to the laboratory, where they were plated in the manner previously described. The results are shown in Table V.



TABLE V.—Variation in bacterial content of samples of ice cream taken from the same freezer.

| Date samples taken. | Sam-<br>ple<br>No. | Number of<br>colonies on<br>duplicate<br>plates (1/1000<br>c. c. plated). |       | Average<br>counts<br>per c. c. | Variation between<br>lowest and highest<br>counts. |
|---------------------|--------------------|---------------------------------------------------------------------------|-------|--------------------------------|----------------------------------------------------|
| 9-14-14.....        | 1                  | 48                                                                        | 56    | 52,000                         | Samples 7 and 9,<br>31.39 per cent.                |
|                     | 2                  | 66                                                                        | 47    | 56,500                         |                                                    |
|                     | 3                  | 48                                                                        | 46    | 47,000                         |                                                    |
|                     | 4                  | 60                                                                        | 43    | 51,500                         |                                                    |
|                     | 5                  | 46                                                                        | 56    | 51,000                         |                                                    |
|                     | 6                  | 51                                                                        | 50    | 50,500                         |                                                    |
|                     | 7                  | 61                                                                        | 52    | 56,500                         |                                                    |
|                     | 8                  | 52                                                                        | 48    | 50,000                         |                                                    |
|                     | 9                  | 42                                                                        | 44    | 43,000                         |                                                    |
| 9-15-14.....        | 1                  | 22                                                                        | ----- | 22,000                         | Samples 4 and 5,<br>29.54 per cent.                |
|                     | 2                  | 25                                                                        | 24    | 24,500                         |                                                    |
|                     | 3                  | 28                                                                        | 22    | 25,000                         |                                                    |
|                     | 4                  | 29                                                                        | 28    | 28,500                         |                                                    |
|                     | 5                  | 22                                                                        | ----- | 22,000                         |                                                    |
|                     | 6                  | 23                                                                        | 26    | 24,500                         |                                                    |
| 9-16-14.....        | 1                  | 107                                                                       | ----- | 107,000                        | Samples 6 and 7,<br>7.84 per cent.                 |
|                     | 2                  | 102                                                                       | ----- | 102,000                        |                                                    |
|                     | 3                  | 110                                                                       | 100   | 105,000                        |                                                    |
|                     | 4                  | 118                                                                       | ----- | 118,000                        |                                                    |
|                     | 5                  | 104                                                                       | ----- | 104,000                        |                                                    |
|                     | 6                  | 102                                                                       | ----- | 102,000                        |                                                    |
|                     | 7                  | 110                                                                       | ----- | 110,000                        |                                                    |
| 9-17-14 (A).....    | 1                  | 58                                                                        | 55    | 56,500                         | Samples 1 and 3,<br>28.41 per cent.                |
|                     | 2                  | 53                                                                        | ----- | 53,000                         |                                                    |
|                     | 3                  | 44                                                                        | ----- | 44,000                         |                                                    |
|                     | 4                  | 52                                                                        | ----- | 52,000                         |                                                    |
|                     | 5                  | 53                                                                        | 52    | 52,500                         |                                                    |
|                     | 6                  | 56                                                                        | 46    | 51,000                         |                                                    |
|                     | 7                  | 53                                                                        | ----- | 53,000                         |                                                    |
|                     | 8                  | 58                                                                        | 53    | 55,500                         |                                                    |
|                     | 9                  | 53                                                                        | ----- | 53,000                         |                                                    |
|                     | 10                 | 53                                                                        | 49    | 51,000                         |                                                    |
| 9-17-14 (A).....    | 1                  | 52                                                                        | ----- | 52,000                         | Samples 3 and 6,<br>25 per cent.                   |
|                     | 2                  | 45                                                                        | 52    | 48,500                         |                                                    |
|                     | 3                  | 53                                                                        | 57    | 55,000                         |                                                    |
|                     | 4                  | 45                                                                        | ----- | 45,000                         |                                                    |
|                     | 5                  | 55                                                                        | 39    | 47,000                         |                                                    |
|                     | 6                  | 40                                                                        | 48    | 44,000                         |                                                    |
|                     | 7                  | 44                                                                        | 51    | 47,500                         |                                                    |
|                     | 8                  | 48                                                                        | 50    | 49,000                         |                                                    |
|                     | 9                  | 42                                                                        | 47    | 44,500                         |                                                    |
|                     | 10                 | 47                                                                        | ----- | 47,000                         |                                                    |
| 9-18-14 (B).....    | 1                  | 159                                                                       | 155   | 157,000                        | Samples 3 and 10,<br>35.87 per cent.               |
|                     | 2                  | 156                                                                       | 157   | 156,500                        |                                                    |
|                     | 3                  | 167                                                                       | 189   | 178,000                        |                                                    |
|                     | 4                  | 164                                                                       | 162   | 163,000                        |                                                    |
|                     | 5                  | 126                                                                       | 173   | 149,500                        |                                                    |
|                     | 6                  | 149                                                                       | 144   | 146,500                        |                                                    |
|                     | 7                  | 157                                                                       | 160   | 158,500                        |                                                    |
|                     | 8                  | 157                                                                       | 154   | 155,500                        |                                                    |
|                     | 9                  | 130                                                                       | 160   | 145,000                        |                                                    |
|                     | 10                 | 131                                                                       | ----- | 131,000                        |                                                    |
| 9-18-14 (B).....    | 1                  | 186                                                                       | 160   | 173,000                        | Samples 3 and 9,<br>30.07 per cent.                |
|                     | 2                  | 157                                                                       | ----- | 157,000                        |                                                    |
|                     | 3                  | 168                                                                       | 227   | 192,500                        |                                                    |
|                     | 4                  | 179                                                                       | ----- | 179,000                        |                                                    |
|                     | 5                  | 166                                                                       | ----- | 166,000                        |                                                    |
|                     | 6                  | 185                                                                       | ----- | 185,000                        |                                                    |
|                     | 7                  | 178                                                                       | ----- | 178,000                        |                                                    |
|                     | 8                  | 165                                                                       | ----- | 165,000                        |                                                    |
|                     | 9                  | 148                                                                       | ----- | 148,000                        |                                                    |
|                     | 10                 | 168                                                                       | ----- | 168,000                        |                                                    |
| 9-19-14.....        | 1                  | 82                                                                        | 77    | 79,500                         | Samples 3 and 5,<br>40.47 per cent.                |
|                     | 2                  | 83                                                                        | ----- | 83,000                         |                                                    |
|                     | 3                  | 94                                                                        | 83    | 88,500                         |                                                    |
|                     | 4                  | 85                                                                        | 84    | 84,500                         |                                                    |
|                     | 5                  | 55                                                                        | 71    | 63,000                         |                                                    |
|                     | 6                  | 98                                                                        | 68    | 83,000                         |                                                    |
|                     | 7                  | 82                                                                        | ----- | 82,000                         |                                                    |
|                     | 8                  | 83                                                                        | 75    | 79,000                         |                                                    |

It will be seen from the table that the highest variation among the samples taken from any freezer was 40.47 per cent, the minimum count in that case being 63,000 and the maximum 88,500 bacteria per cubic centimeter. The lowest variation was 7.84 per cent, the counts in this instance ranging from 102,000 to 118,000 per cubic centimeter.

It is interesting to note that the two sets of samples marked A were taken on the same day from two different freezers, which were probably filled with the same "mix." The same is true of the sets marked B. In each of these cases the samples check well with each other. From these results it seems evident that the bacterial content of one sample from a freezer may be said to represent for practical purposes the bacterial content of the rest of the ice cream in the freezer.

#### COMPARISON OF INCUBATION OF PLATES AT 37° C. FOR TWO DAYS AND 30° C. FOR FIVE DAYS.

The plates in our experiments were incubated at 30° C. (86° F.) for five days. Since in general practice plates are incubated at 37° C. (98.6° F.) and counts made after 48 hours, it was considered advisable to make a comparison between these two methods of incubation.

A gallon of ice cream was obtained and nine samples taken from nine different positions in the usual manner. Two sets of duplicate plates were made; one set was incubated at 37° C. (98.6° F.) and counted after 48 hours. The other set was incubated at 30° C. (86° F.) and counted after five days. The results of this experiment (see Table VI) show that the variation among the samples from the same lot of ice cream was 16.89 per cent after the 48-hour count at 37° C. (98.6° F.) and 35.11 per cent after incubation at 30° C. for five days.

From this experiment it seems evident that incubation at 37° C. (98.6° F.) for 48 hours does not give counts which show any greater variation than those obtained by incubation at 30° C. (86° F.) for five days. It is interesting to observe, however, that the count obtained by incubation for five days at 30° C. (86° F.) is practically double that obtained by incubation at 37° C. (98.6° F.) for 48 hours.

TABLE VI.—*Variation in counts obtained by incubation of plates at 37° C. for two days and 30° C. for five days.*

| Sample No. | Incubated at 37° C. for 48 hours.       |                         |                                              | Incubated at 30° C. for 5 days.         |                         |                                              |
|------------|-----------------------------------------|-------------------------|----------------------------------------------|-----------------------------------------|-------------------------|----------------------------------------------|
|            | Number of bacteria on duplicate plates. | Average count per c. c. | Variation between lowest and highest counts. | Number of bacteria on duplicate plates. | Average count per c. c. | Variation between lowest and highest counts. |
| 1          | 77                                      | 80                      | 785,000                                      | 170                                     | 176                     | 1,730,000                                    |
| 2          | 74                                      | .....                   | 740,000                                      | 161                                     | .....                   | 1,610,000                                    |
| 3          | 77                                      | .....                   | 770,000                                      | 161                                     | 183                     | 1,720,000                                    |
| 4          | 76                                      | 79                      | 775,000                                      | 179                                     | 165                     | 1,720,000                                    |
| 5          | 81                                      | 83                      | 820,000                                      | 162                                     | 192                     | 1,770,000                                    |
| 6          | 75                                      | 82                      | 785,000                                      | 174                                     | .....                   | 1,740,000                                    |
| 7          | 73                                      | 80                      | 765,000                                      | 131                                     | .....                   | 1,310,000                                    |
| 8          | 80                                      | .....                   | 800,000                                      | 184                                     | 143                     | 1,835,000                                    |
| 9          | 83                                      | 90                      | 865,000                                      | 157                                     | .....                   | 1,570,000                                    |
|            |                                         |                         | Samples 2 and 9,<br>16.89 per cent.          |                                         |                         | Samples 5 and 7,<br>35.11 per cent.          |

## THE NUMBER OF COLONIES MOST DESIRABLE ON PETRI PLATES.

When a sample of ice cream is plated it is of course necessary to make several dilutions, since the bacterial content is unknown. It is sometimes a question as to which dilution will give the most accurate count.

Some interesting facts regarding this point are shown by reference to Table VII. Seven 1-gallon lots of ice cream were obtained, and nine samples from each were plated in the usual manner. Three dilutions were made, but only two are recorded in the table. The aim was to obtain plates with about 200 colonies, as in bacteriological work that number is believed to give the most nearly accurate count. The two recorded, therefore, are the counts obtained from the dilution which gave about 200 colonies per plate and the counts from the next highest dilution.

An examination of the table shows that the variation between samples taken from the same lot of ice cream ranged from 15.10 to 105.32 per cent when the dilution was such that from 100 to 300 colonies were on the plates. The same samples at the next higher dilution, in which the number of colonies was less than 50, varied from 35 to 1,014.28 per cent. In every case in which there was a small number of colonies on the plates the variation between the samples from each gallon lot was decidedly greater than when a lower dilution was used. This fact is by no means new, but it should be kept in mind when interpreting the results obtained from a bacterial analysis of duplicate samples of ice cream.

TABLE VII.—Comparison of bacterial counts obtained from the same samples of ice cream but with different dilutions.

| Lot.  | Sam-<br>ple<br>No. | Dilu-<br>tion. | Number of<br>colonies on<br>duplicate<br>plates. |       | Average<br>count per<br>c. c. | Vari-<br>ation be-<br>tween<br>lowest<br>and<br>highest<br>counts. | Dilution. | Num-<br>ber of<br>colonies<br>on du-<br>plicate<br>plates. |       | Average<br>count per<br>c. c. | Vari-<br>ation be-<br>tween<br>lowest<br>and<br>highest<br>counts. |
|-------|--------------------|----------------|--------------------------------------------------|-------|-------------------------------|--------------------------------------------------------------------|-----------|------------------------------------------------------------|-------|-------------------------------|--------------------------------------------------------------------|
| A.... | 1                  | 1:10000        | 243                                              | 229   | 2,360,000                     | Per ct.<br>21.34                                                   | 1:10000   | 27                                                         | 30    | 2,850,000                     | Per ct.<br>36.36                                                   |
|       | 2                  |                | 219                                              | 198   | 2,085,000                     |                                                                    |           | 22                                                         | 43    | 3,250,000                     |                                                                    |
|       | 3                  |                | 242                                              | 243   | 2,425,000                     |                                                                    |           | 24                                                         | 40    | 3,200,000                     |                                                                    |
|       | 4                  |                | 231                                              | 245   | 2,380,000                     |                                                                    |           | 36                                                         | 24    | 3,000,000                     |                                                                    |
|       | 5                  |                | 250                                              | ..... | 2,500,000                     |                                                                    |           | 36                                                         | 39    | 3,750,000                     |                                                                    |
|       | 6                  |                | 264                                              | 233   | 2,485,000                     |                                                                    |           | 30                                                         | 25    | 2,750,000                     |                                                                    |
|       | 7                  |                | 230                                              | ..... | 2,300,000                     |                                                                    |           | 37                                                         | 28    | 3,250,000                     |                                                                    |
|       | 8                  |                | 243                                              | 245   | 2,440,000                     |                                                                    |           | 36                                                         | 22    | 2,900,000                     |                                                                    |
|       | 9                  |                | 271                                              | 235   | 2,530,000                     |                                                                    |           | 34                                                         | 25    | 2,950,000                     |                                                                    |
| B.... | 1                  | 1:100000       | 341                                              | 334   | 33,750,000                    | 25.00                                                              | 1:100000  | 41                                                         | 31    | 36,000,000                    | 35.00                                                              |
|       | 2                  |                | 274                                              | 266   | 27,000,000                    |                                                                    |           | 31                                                         | 29    | 30,000,000                    |                                                                    |
|       | 3                  |                | 284                                              | ..... | 28,400,000                    |                                                                    |           | 30                                                         | ..... | 30,000,000                    |                                                                    |
|       | 4                  |                | 294                                              | 302   | 29,800,000                    |                                                                    |           | 30                                                         | ..... | 30,000,000                    |                                                                    |
|       | 5                  |                | 284                                              | 270   | 27,700,000                    |                                                                    |           | 33                                                         | 36    | 34,500,000                    |                                                                    |
|       | 6                  |                | 301                                              | 303   | 30,200,000                    |                                                                    |           | 38                                                         | 29    | 33,500,000                    |                                                                    |
|       | 7                  |                | 325                                              | 331   | 32,800,000                    |                                                                    |           | 38                                                         | 44    | 41,000,000                    |                                                                    |
|       | 8                  |                | 321                                              | 329   | 32,500,000                    |                                                                    |           | 35                                                         | 43    | 39,000,000                    |                                                                    |
|       | 9                  |                | 314                                              | ..... | 31,400,000                    |                                                                    |           | 35                                                         | 46    | 40,500,000                    |                                                                    |
| C.... | 1                  | 1:10000        | 286                                              | 290   | 288,000                       | 22.31                                                              | 1:10000   | 42                                                         | 53    | 475,000                       | 50.79                                                              |
|       | 2                  |                | 360                                              | 254   | 307,000                       |                                                                    |           | 41                                                         | ..... | 410,000                       |                                                                    |
|       | 3                  |                | 270                                              | 289   | 279,500                       |                                                                    |           | 40                                                         | 33    | 365,000                       |                                                                    |
|       | 4                  |                | 250                                              | 270   | 260,000                       |                                                                    |           | 31                                                         | 42    | 365,000                       |                                                                    |
|       | 5                  |                | 314                                              | 250   | 282,000                       |                                                                    |           | 38                                                         | 39    | 385,000                       |                                                                    |
|       | 6                  |                | 251                                              | 252   | 251,500                       |                                                                    |           | 30                                                         | 33    | 315,000                       |                                                                    |
|       | 7                  |                | 268                                              | 250   | 259,000                       |                                                                    |           | 32                                                         | 38    | 350,000                       |                                                                    |
|       | 8                  |                | 311                                              | 287   | 299,000                       |                                                                    |           | 32                                                         | 44    | 380,000                       |                                                                    |
|       | 9                  |                | 261                                              | 306   | 283,500                       |                                                                    |           | 35                                                         | 52    | 435,000                       |                                                                    |



TABLE VII.—Comparison of bacterial counts obtained from the same samples of ice cream but with different dilutions—Continued.

| Lot.   | Sample No. | Dilution. | Number of colonies on duplicate plates. |     | Average count per c. c. | Variation between lowest and highest counts. | Dilution. | Number of colonies on duplicate plates. |     | Average count per c. c. | Variation between lowest and highest counts. |
|--------|------------|-----------|-----------------------------------------|-----|-------------------------|----------------------------------------------|-----------|-----------------------------------------|-----|-------------------------|----------------------------------------------|
| D ...  | 1          | 1:100,000 | 321                                     | 310 | 31,500,000              | Per ct.<br>63.47                             | 1:100,000 | 22                                      | 31  | 26,500,000              | Per ct.<br>88.69                             |
|        | 2          |           | 270                                     | 305 | 28,750,000              |                                              |           | 35                                      | 36  | 35,500,000              |                                              |
|        | 3          |           | 386                                     | 372 | 37,900,000              |                                              |           | 24                                      | 37  | 30,500,000              |                                              |
|        | 4          |           | 278                                     | 305 | 29,150,000              |                                              |           | 33                                      | 25  | 29,000,000              |                                              |
|        | 5          |           | 367                                     | 356 | 36,150,000              |                                              |           | 35                                      | 34  | 34,500,000              |                                              |
|        | 6          |           | 354                                     | 357 | 35,550,000              |                                              |           | 35                                      | ... | 35,000,000              |                                              |
|        | 7          |           | 431                                     | 466 | 44,850,000              |                                              |           | 43                                      | 27  | 35,000,000              |                                              |
|        | 8          |           | 470                                     | ... | 47,000,000              |                                              |           | 52                                      | 39  | 45,500,000              |                                              |
|        | 9          |           | 434                                     | ... | 43,400,000              |                                              |           | 55                                      | 45  | 50,000,000              |                                              |
| E .... | 1          | 1:100,000 | 219                                     | 186 | 202,500                 | 15.10                                        | 1:100,000 | 24                                      | 20  | 220,000                 | 105.71                                       |
|        | 2          |           | 214                                     | ... | 214,000                 |                                              |           | 25                                      | ... | 250,000                 |                                              |
|        | 3          |           | 222                                     | 190 | 206,000                 |                                              |           | 23                                      | 24  | 235,000                 |                                              |
|        | 4          |           | 192                                     | ... | 192,000                 |                                              |           | 13                                      | 22  | 175,000                 |                                              |
|        | 5          |           | 212                                     | 194 | 203,000                 |                                              |           | 26                                      | 16  | 210,000                 |                                              |
|        | 6          |           | 197                                     | 200 | 198,500                 |                                              |           | 36                                      | ... | 360,000                 |                                              |
|        | 7          |           | 212                                     | 208 | 210,000                 |                                              |           | 20                                      | 24  | 220,000                 |                                              |
|        | 8          |           | 231                                     | 205 | 218,000                 |                                              |           | 31                                      | 25  | 280,000                 |                                              |
|        | 9          |           | 218                                     | 224 | 221,000                 |                                              |           | 36                                      | 22  | 290,000                 |                                              |
| F .... | 1          | 1:100,000 | 310                                     | 298 | 30,400,000              | 17.85                                        | 1:100,000 | 19                                      | 13  | 16,000,000              | 131.25                                       |
|        | 2          |           | 286                                     | ... | 28,600,000              |                                              |           | 27                                      | 29  | 28,000,000              |                                              |
|        | 3          |           | 330                                     | ... | 33,000,000              |                                              |           | 21                                      | 22  | 21,500,000              |                                              |
|        | 4          |           | 293                                     | 288 | 29,050,000              |                                              |           | 29                                      | 22  | 25,500,000              |                                              |
|        | 5          |           | 284                                     | 288 | 28,600,000              |                                              |           | 31                                      | 28  | 29,500,000              |                                              |
|        | 6          |           | 328                                     | 292 | 31,000,000              |                                              |           | 36                                      | 31  | 33,500,000              |                                              |
|        | 7          |           | 286                                     | 278 | 28,200,000              |                                              |           | 35                                      | 39  | 37,000,000              |                                              |
|        | 8          |           | 275                                     | 285 | 28,000,000              |                                              |           | 27                                      | 32  | 29,500,000              |                                              |
| G .... | 1          | 1:100,000 | 144                                     | 178 | 16,100,000              | 105.22                                       | 1:100,000 | 22                                      | 20  | 21,000,000              | 1,014.28                                     |
|        | 2          |           | 128                                     | 136 | 13,200,000              |                                              |           | 17                                      | 47  | 32,000,000              |                                              |
|        | 3          |           | 179                                     | 161 | 17,000,000              |                                              |           | 7                                       | 14  | 10,500,000              |                                              |
|        | 4          |           | 200                                     | ... | 20,000,000              |                                              |           | 30                                      | 14  | 22,000,000              |                                              |
|        | 5          |           | 235                                     | 190 | 21,250,000              |                                              |           | 6                                       | 1   | 3,500,000               |                                              |
|        | 6          |           | 152                                     | ... | 15,200,000              |                                              |           | 15                                      | 15  | 15,000,000              |                                              |
|        | 7          |           | 130                                     | 133 | 13,150,000              |                                              |           | 15                                      | 9   | 12,000,000              |                                              |
|        | 8          |           | 270                                     | ... | 27,000,000              |                                              |           | 38                                      | ... | 38,000,000              |                                              |
|        | 9          |           | 222                                     | ... | 22,200,000              |                                              |           | 33                                      | 45  | 39,000,000              |                                              |

#### VARIATION BETWEEN DUPLICATE COUNTS FROM SAME SAMPLE AND SAME DILUTION.

As stated, we do not intend to say just what variation should be allowed between duplicate counts or a series of samples of ice cream from the same lot. Table VIII, however, shows some colony counts obtained by making a series of from five to eight plates from the same dilution. In five different samples a variation of from 7 to 26.6 per cent was found. Among the duplicate plates in the examination of other samples of ice cream a variation as high as 41 per cent was found. From figures given by other investigators of the results of bacterial counts of ice cream, variations in counts between duplicate plates as high as 88 per cent have been observed. It is obvious that the factor of variation among plates from the same dilution of ice cream must be taken into consideration when interpreting the results of the bacterial analysis of duplicate samples or a series of samples from a given mass of ice cream. To this factor of variation must be also added that caused by the difficulty of removing exactly equal quantities of different samples of ice cream in order to make the first dilution.

TABLE VIII.—*Colony counts on duplicate plates from the same dilution of a sample of ice cream.*

| Sample No. | Number of colonies on duplicate plates. |     |     |     |     |       |       |       | Variation. |
|------------|-----------------------------------------|-----|-----|-----|-----|-------|-------|-------|------------|
|            | 1                                       | 2   | 3   | 4   | 5   | 6     | 7     | 8     |            |
| 1          | 243                                     | 229 | 225 | 208 | 232 | 218   | ----- | ----- | Percent.   |
| 2          | 450                                     | 460 | 510 | 470 | 450 | 470   | 500   | 570   | 16.8       |
| 3          | 321                                     | 302 | 307 | 300 | 310 | ----- | ----- | ----- | 26.6       |
| 4          | 319                                     | 310 | 267 | 298 | 280 | ----- | ----- | ----- | 7.0        |
| 5          | 144                                     | 152 | 153 | 178 | 178 | ----- | ----- | ----- | 19.4       |
|            |                                         |     |     |     |     |       |       |       | 23.6       |

## INTERPRETING DIFFERENCES IN BACTERIAL COUNTS.

When expressing bacterial counts the mere statement of the difference in the number of bacteria between two samples is not sufficient; in fact, it is impossible to interpret such differences properly without taking into consideration the total number of bacteria found in each sample. If, for example, it is stated that 1 cubic centimeter of ice cream contains 75,000,000 more bacteria than another sample, the difference of so many millions conveys to the mind a marked disparity in the two samples. If, on the other hand, there is said to be a difference of only 750 or 7,500 bacteria per cubic centimeter, we should immediately think of the samples as being practically the same.

TABLE IX.—*Hypothetical statement showing variable differences in bacterial counts of two samples of ice cream having a fixed ratio between colony counts and a fixed per cent of variation.*

| Colony     | Dilution.            | Bacteria per c. c.             | Difference in count. | Variation between counts. |
|------------|----------------------|--------------------------------|----------------------|---------------------------|
|            |                      |                                |                      | Per cent.                 |
| 375<br>300 | 1 to 10.....         | 3,750<br>3,000                 | 750                  | 25.00                     |
| 375<br>300 | 1 to 100.....        | 37,500<br>30,000               | 7,500                | 25.00                     |
| 375<br>300 | 1 to 1,000.....      | 375,000<br>300,000             | 75,000               | 25.00                     |
| 375<br>300 | 1 to 10,000.....     | 3,750,000<br>3,000,000         | 750,000              | 25.00                     |
| 375<br>300 | 1 to 100,000.....    | 37,500,000<br>30,000,000       | 7,500,000            | 25.00                     |
| 375<br>300 | 1 to 1,000,000.....  | 375,000,000<br>300,000,000     | 75,000,000           | 25.00                     |
| 375<br>300 | 1 to 10,000,000..... | 3,750,000,000<br>3,000,000,000 | 750,000,000          | 25.00                     |

Let us consider a hypothetical case, as shown in Table IX. We will assume that one sample of ice cream shows an average colony count of 375 and another 300. With a dilution of from 1 to 10, there would be a total count of 3,750 in one sample and 3,000 in the other, a difference of 750 bacteria per cubic centimeter, and a variation of 25 per cent between counts. If the same colony count were from a dilution of from 1 to 100 the difference in the bacteria in the samples would be 7,500, but the variation would be still the

same, or 25 per cent. As the total count becomes still higher, necessitating higher dilutions, the difference in bacteria per cubic centimeter increases until at a dilution of from 1 to 1,000,000 the difference would be 75,000,000 per cubic centimeter.

A study of this assumed case merely serves to show that even though there is a difference of 75,000,000 between two samples of ice cream, there is no greater percentage of variation between the samples than when the difference was only 750 per cubic centimeter. It also shows, however, that a difference between counts expressed in bacteria per cubic centimeter should never be considered by itself but should be interpreted in relation to the total number of bacteria per cubic centimeter in each sample.

### SUMMARY AND CONCLUSIONS.

The method of collecting samples and making bacterial counts used in our experiments gives results which indicate that bacteria in commercial ice cream are distributed quite evenly and that an analysis of one sample from a gallon of ice cream gives results which will hold for any other similar sample from the same gallon.

Storage of ice cream for 11 days in a commercial ice-cream cabinet or in a hardening room for a period of two months did not seem to cause an uneven distribution of bacteria.

In a series of from 5 to 10 samples taken directly from a large commercial freezer the bacterial counts on each sample checked within the usual limits of error of bacterial analyses.

No greater variation in bacterial counts between samples was observed when the plates were incubated at 37° C. (98.6° F.) for 48 hours than when incubated at 30° C. (86° F.) for a period of five days.

When dilutions were such that about 200 colonies were present on the plates a lower variation between counts of samples of ice cream was found than when there were 50 or fewer colonies per plate.

The variation between a series of plates made from the same sample and dilution was found to range from 7 to 26.6 per cent. Among duplicate plates a variation as high as 41 per cent was observed. This must be remembered in connection with the fact that the variation found in our experiments between average counts of different samples of ice cream from the same gallon lot ranged, generally speaking, between 20 and 30 per cent. To this variation between duplicate plates or a series of plates from the same dilution must be added the error introduced in removing 1 c. c. portions of ice cream from different samples.

When interpreting bacterial counts, differences in the number of bacteria per cubic centimeter should never be considered except in relation to the total count of each sample.



# UNITED STATES DEPARTMENT OF AGRICULTURE



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Contribution from Bureau of Entomology  
L. O. HOWARD, Chief



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### COLLECTION OF WEEVILS AND INFESTED SQUARES AS A MEANS OF CONTROL OF THE COTTON-BOLL WEEVIL IN THE MISSISSIPPI DELTA.

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Insect Investigations.*

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#### GENERAL STATEMENT OF EXPERIMENTS CONDUCTED.

During the cotton-growing seasons of 1915 and 1916 the writers conducted a series of studies to ascertain the value of various methods of collecting boll weevils and infested cotton forms as a means of control for the cotton-boll weevil. The experimental work was conducted in the vicinity of Tallulah, La., while more or less extensive observations were made at various points throughout Louisiana and Mississippi. The following studies apply most directly to the conditions existing in what is termed the "Delta" of Louisiana and Mississippi, but are also undoubtedly applicable to other portions of the cotton belt where a severe weevil infestation prevails.

In July, 1916, the senior writer published a preliminary report on the results of the 1915 studies<sup>1</sup> in order to place the information secured in a form available for use by the planters.

NOTE.—This bulletin will be of interest to entomologists and to cotton growers in the Delta region of Louisiana.

<sup>1</sup> Coad, B. R. Cotton-boll Weevil Control in the Mississippi Delta, with Special Reference to Square Picking and Weevil Picking. U. S. Dept. Agr. Bul. 382, July 8, 1916.

The investigations of 1916 were conducted under seasonal and climatic conditions differing considerably from those of 1915 and were more extensive, so that it seems that the combined results of the two seasons' investigations may be considered as more or less conclusive. The following report presents a rather brief summary of these experiments, together with the conclusions which seem warranted by the observations.

The various field experiments were conducted by the junior writer and Messrs. W. B. Williams and T. P. Cassidy, under the direction of the senior writer.

#### BRIEF REVIEW OF 1915 EXPERIMENTS.

Before proceeding with a consideration of the investigations of 1916 it is probably well to review briefly the results of the 1915 studies, since the program of work for the second year was based upon these results. In 1915, plat tests of the collection of fallen forms in the cotton field gave an increased yield of 23 per cent over the untreated cotton. Similar tests of weevil collection were started and the study of weevil infestation and other observations made during the season indicated that a similar degree of control was being secured. Unfortunately, the weevil-picking test plats of that year were ruined by hail in the latter part of June, so most of the conclusions on weevil picking were based on observations made prior to the hail storm and upon comparative efficiency studies of the various means of collecting adult weevils made later in the season.

The seasonal conditions of 1915 in the neighborhood where these experiments were conducted were very peculiar. Owing to the rather severe winter of 1914-15 the emergence from hibernation in the spring of 1915 was very light and late, resulting in only a slight initial infestation. Following this, the exceedingly dry weather of July produced a very high climatic control of the weevil stages in the fallen forms. This naturally resulted in a comparatively light degree of weevil injury regardless of whether or not control measures were practiced. In view of this very unusually light degree of injury it was considered probable that different seasonal conditions would produce different results from these control measures.

One interesting feature of the investigation of 1915 was the study of different methods of collection of the weevils and infested forms. Consideration of two factors—(1) the labor supply available and (2) the labor required for the hand picking of either the weevils or the infested forms—showed these measures of repression to be impracticable under the average Delta plantation conditions, hence an effort was made to find some way of reducing the labor requirements of the picking operation. The most promising method considered in this

connection was the use of the bag-and-hoop as a weevil collector. This semimechanical method, which has been explained in detail in the earlier bulletin, proved to collect more weevils in less time than did hand picking, and as an additional advantage gathered a considerable number of infested squares and bolls during the course of the shaking operation. As it was so well adapted to the type of labor available and as it considerably reduced the amount of labor required, this method appeared to give the greatest promise of success. Consequently the investigations of 1916, which largely employed the bag-and-hoop method of collection, were aimed at securing information on the exact degree of control exerted by its use in the field under varying conditions.

-                      LINES OF INVESTIGATION IN 1916.

The experiments of 1916 may be divided into three more or less distinct lines of investigation. These were: (1) Plat tests under field conditions to determine the degree of weevil control produced by the operation of the bag-and-hoop for different periods at various time intervals between pickings; (2) intensive studies on the relation of the time interval between the pickings to the proportion of the infested forms collected in the bag; and (3) studies on the efficiency of certain mechanical collectors.

**TIME INTERVAL BETWEEN BAG-AND-HOOP COLLECTIONS IN RELATION TO PROPORTION OF INFESTED FORMS SECURED.**

As has been stated, one of the favorable features attending the use of the bag-and-hoop as a means of collecting weevils was the collection of the infested squares and bolls while shaking the plants for the weevils. Thus this operation to some extent combined the results secured from two operations—(1) hand picking of weevils and (2) hand picking of infested forms. However, in attempting to outline some scheme for the practical use of the bag-and-hoop in the field it was necessary to know just what proportion of the forms falling to the ground because of weevil injury would be collected at different time intervals between pickings. In other words, it seemed desirable to find just what time interval would be necessary to secure the largest proportion of the infested squares and still be feasible for use. Indirect information on this score was of course secured from the general field tests of the use of this method of control; but, in addition to these, an intensive study was conducted by Mr. Williams on Eureka plantation, near Tallulah, La. The idea of this study was not so much to secure information on the actual degree of weevil control exerted by this operation in the plats under observation, but to secure information on the forms collected in the bags and the



forms reaching the ground in the different plats. As one of the larger field tests of the bag-and-hoop method was also located on this same plantation, this intensive study was termed "Eureka Experiment No. 2."

#### DESCRIPTION OF PLATS.

For conducting this study a small block of cotton was selected in the center of the cut. This cotton was a part of the general planting of the cut and was farmed exactly the same as the surrounding cotton throughout the season. The experimental area considered was 32 rows in width and 150 feet long. This was divided into eight plats of four rows each. The two outside plats were left untreated as checks, while plat 1 was shaken with the bag-and-hoop six times a week; plat 2, five times; plat 3, four times; plat 4, three times; plat 5, twice; and plat 6 once a week during the experimental period. These pickings were distributed through the week as well as possible. In addition to picking these plats a strip 30 feet in length beyond the end of each plat was gone over each time that the adjoining plat was picked. This was done simply to provide a buffer system which would protect the plats from an immigration of weevils from unpicked cotton.

The cotton variety used in these plats was the Simpkin's Ideal, and a good stand prevailed at the beginning of the experiment.

#### METHOD OF OPERATION.

The method of collection used in these plats was the ordinary system of bag-and-hoop shaking, the plants being shaken into a sack held open by a hoop sewn in the mouth.

Negro laborers were used for the work, but they were under the constant supervision of an entomologist, and care was taken to make the work very thorough. Unnecessary injury to the plants was avoided as much as possible. At the beginning of the season bags about 20 inches in diameter were used for the small plants, but these were later replaced by considerably larger ones which allowed a reasonably thorough treatment as long as the pickings were continued.

The pickings were started on June 12. The plats had been watched carefully for some weeks before that time in order to start the picking as soon as the weevils became sufficiently abundant to make the records of any value. The initial spring infestation in this particular cut of cotton was rather light, and it was not until about this date that any weevils could be located in the plats. Following this first picking the schedule mentioned was continued for nine weeks, thus making the total pickings of the different plats range from 9 in plat 6 to 54 in plat 1.

## WEEVILS COLLECTED.

Throughout the experimental period a record was kept of the number of weevils gathered from each row of each plat at each picking. These records are only of incidental interest, as the extreme smallness of the plats, of course, allowed more or less of an interplat movement of weevils every day, and the records secured bear no relation to the conditions which would exist if larger tracts were picked at the different time intervals. However, the row and plat totals and plat averages for the season are of some interest and are given in Table 1.

TABLE 1.—*Total number of weevils collected, by rows and plats, Eureka plantation, Tallulah, La., 1916.*

| Plat No. | Total<br>number<br>of<br>pickings. | Row No.<br>1. | Row No.<br>2. | Row No.<br>3. | Row No.<br>4. | Plat<br>total. | Average<br>per<br>picking<br>for plat. |
|----------|------------------------------------|---------------|---------------|---------------|---------------|----------------|----------------------------------------|
| 1.....   | 54                                 | 275           | 257           | 130           | 210           | 872            | 16.1                                   |
| 2.....   | 45                                 | 229           | 203           | 184           | 176           | 792            | 17.5                                   |
| 3.....   | 36                                 | 169           | 167           | 243           | 176           | 755            | 20.9                                   |
| 4.....   | 27                                 | 127           | 174           | 100           | 136           | 537            | 19.8                                   |
| 5.....   | 18                                 | 92            | 114           | 108           | 110           | 424            | 23.5                                   |
| 6.....   | 9                                  | 81            | 60            | 84            | 62            | 287            | 31.8                                   |

From this table it is seen that, generally speaking, the weevils per picking increased about in proportion to the increase in the time interval between pickings. However, the average number of weevils per picking in plat 6 was only twice that of plat 1, whereas plat 1 was picked six times as often as plat 6. The fact that there was an increase in the number of weevils secured per picking with the decrease in the number of pickings shows that the weevil movement within even these small plats was at least not sufficient to equalize the distribution completely throughout the plats between the pickings. This point is of principal interest in connection with the consideration of the important question of the extent and effect of the interplat movement of weevils in the larger field tests, which will be discussed later in the present report.

## FORMS COLLECTED IN BAGS.

In the same way that the weevil collections were recorded the forms gathered in the sacks from each row at each picking were noted. These forms were examined each time and divided into squares and bolls; then these were redivided into those uninjured (termed "clean"), those weevil punctured, and those showing other injury, such as rot, worm injury, etc. The plat totals secured during the different pickings are shown in Table 2, and are rearranged in Table 3 to show the averages per picking for each plat.

TABLE 2.—*Total number of forms collected in bags and percentage injured, Eureka plantation, Tallulah, La., 1916.*

| Plat No.                  | Bolls.      |              |                      |              |                    |              |                                         | Squares.    |              |                      |              |                    |              |                          | Total<br>bolls<br>and<br>squares<br>col-<br>lected. |
|---------------------------|-------------|--------------|----------------------|--------------|--------------------|--------------|-----------------------------------------|-------------|--------------|----------------------|--------------|--------------------|--------------|--------------------------|-----------------------------------------------------|
|                           | Clean.      |              | Weevil<br>punctured. |              | Other in-<br>jury. |              | Total<br>num-<br>ber<br>col-<br>lected. | Clean.      |              | Weevil<br>punctured. |              | Other in-<br>jury. |              | Total<br>col-<br>lected. |                                                     |
|                           | To-<br>tal. | Per<br>cent. | To-<br>tal.          | Per<br>cent. | To-<br>tal.        | Per<br>cent. |                                         | To-<br>tal. | Per<br>cent. | To-<br>tal.          | Per<br>cent. | To-<br>tal.        | Per<br>cent. |                          |                                                     |
| 1 .....                   | 1,224       | 44.5         | 770                  | 28.0         | 755                | 27.5         | 2,749                                   | 1,435       | 33.7         | 2,740                | 64.2         | 91                 | 2.1          | 4,266                    | 7,015                                               |
| 2 .....                   | 800         | 42.9         | 577                  | 31.0         | 486                | 26.1         | 1,863                                   | 1,362       | 30.2         | 3,073                | 68.0         | 82                 | 1.8          | 4,517                    | 6,380                                               |
| 3 .....                   | 610         | 37.9         | 481                  | 29.8         | 520                | 32.3         | 1,611                                   | 1,424       | 32.0         | 2,969                | 66.6         | 64                 | 1.4          | 4,457                    | 6,068                                               |
| 4 .....                   | 633         | 44.4         | 422                  | 29.7         | 368                | 25.9         | 1,423                                   | 726         | 25.8         | 2,027                | 72.0         | 63                 | 2.2          | 2,816                    | 4,239                                               |
| 5 .....                   | 171         | 28.1         | 246                  | 40.2         | 195                | 31.7         | 612                                     | 686         | 26.4         | 1,813                | 71.4         | 55                 | 2.2          | 2,554                    | 3,166                                               |
| 6 .....                   | 121         | 35.7         | 118                  | 34.8         | 100                | 29.5         | 339                                     | 562         | 30.7         | 1,240                | 67.6         | 32                 | 1.7          | 1,834                    | 2,173                                               |
| Total .....               | 3,559       | .....        | 2,614                | .....        | 2,424              | .....        | 8,597                                   | 6,195       | .....        | 13,862               | .....        | 387                | .....        | 20,444                   | 29,041                                              |
| Weighted<br>average. .... |             | 41.4         |                      | 30.4         |                    | 28.2         |                                         |             | 30.3         |                      | 67.8         |                    | 1.9          |                          |                                                     |

From Table 2 it is seen that the total forms collected ranged from 2,173 for plat 6 to 7,015 for plat 1. In other words, three times as many forms were gathered in the bags in plat 1 as in plat 6. These figures show the number of forms collected per plat to increase quite rapidly with the increase in the number of pickings. In fact, the average bolls per picking increased somewhat with the increase in the number of pickings per plat. The figures on the percentage infested and clean show this increase to be largely due to the fact that more clean bolls were shaken off as the number of pickings per week was increased. This was quite probably due to the weight of the bolls breaking the stems during the frequently repeated shakings.

The square collections show different results from the boll records just noted. With the squares the increase per collection as the shakings decreased in frequency is marked, ranging from 79 for plat 1 to 204 for plat 6. This difference in results between bolls and squares is probably due to the fact that the clean squares are not broken off in such large numbers by the excessive shakings as are the bolls. In fact, the percentage of clean squares collected in the different plats ranged only from 25.8 per cent to 33.7 per cent, while the clean bolls ranged from 28.1 per cent to 44.5 per cent. Incidentally, these results seem to indicate a rather undesirable amount of loss of clean forms due to the shaking process.

The high percentage of bolls recorded as "other injury" was due to the fact that practically daily rains prevailed in the experimental area during the month of July, and consequently there was a great shedding of young, infertile or rotting bolls. This rain may have increased the natural shedding of clean forms also, and thus raised this percentage above normal. In the total of all the pickings in all plats, one-third (weighted average 33.9 per cent) of the forms col-



lected in the bags were clean. Of course, some of these forms may have belonged to the class which shed normally for physiological causes, but this proportion seems to be very undesirably high.

The fact that the squares collected in plat 1 numbered only two and one-half times as many as in plat 6, in spite of the fact that the former was picked six times as often as the latter, is of interest. This shows that a picking at a weekly interval secures more than that day's pro rata of the squares due to fall.

#### FALLEN FORMS COLLECTED.

As a check on the relative number of forms collected in the bags, the number of forms falling to the ground in each row was also determined. To accomplish this all forms were picked from the ground once a week, beginning June 29. These were examined and sorted into bolls and squares, clean and injured. This sorting was continued until July 31, when it was found that so nearly all fallen forms were injured that they were divided only into bolls and squares. Unfortunately, the forms were not collected from the ground in the checks for the first four weeks. On July 25, however, all forms were cleared from the ground in the checks, and these two plats were included in the last three pickings. This makes it necessary to consider only these three pickings when comparing the picked plats with the checks.

TABLE 3.—Forms collected in bags averaged by pickings, Eureka plantation, Tallulah, La., 1916.

| Plat No. | Times picked. | Bolls collected. |                      | Squares collected. |                      | Total forms collected. |                      |
|----------|---------------|------------------|----------------------|--------------------|----------------------|------------------------|----------------------|
|          |               | Total.           | Average per picking. | Total.             | Average per picking. | Total.                 | Average per picking. |
| 1.....   | 54            | 2,749            | 51                   | 4,266              | 79                   | 7,015                  | 130                  |
| 2.....   | 45            | 1,863            | 41                   | 4,517              | 100                  | 6,380                  | 141                  |
| 3.....   | 36            | 1,611            | 45                   | 4,457              | 123                  | 6,068                  | 168                  |
| 4.....   | 27            | 1,423            | 52                   | 2,816              | 104                  | 4,239                  | 156                  |
| 5.....   | 18            | 612              | 34                   | 2,554              | 142                  | 3,166                  | 176                  |
| 6.....   | 9             | 339              | 37                   | 1,834              | 204                  | 2,173                  | 241                  |

TABLE 4.—*Fallen forms collected. Plat totals at each collection, Eureka plantation Tallulah, La., 1916.*

| Date picked. | Plat 1. |        |          |          |        |          | Plat 2. |        |          |          |        |          |
|--------------|---------|--------|----------|----------|--------|----------|---------|--------|----------|----------|--------|----------|
|              | Bolls.  |        |          | Squares. |        |          | Bolls.  |        |          | Squares. |        |          |
|              | Number. | Clean. | Injured. | Number.  | Clean. | Injured. | Number. | Clean. | Injured. | Number.  | Clean. | Injured. |
| June 29..... |         |        |          | 34       | 13     | 21       |         |        |          | 42       | 18     | 24       |
| July 3.....  | 13      |        |          | 40       | 14     | 26       | 9       |        |          | 16       | 8      | 8        |
| July 10..... | 394     | 108    | 286      | 248      | 58     | 190      | 482     | 152    | 330      | 375      | 181    | 194      |
| July 17..... | 497     | 17     | 480      | 227      | 40     | 187      | 205     | 16     | 189      | 200      | 74     | 126      |
| July 25..... | 900     | 219    | 681      | 465      | 64     | 401      | 889     | 364    | 525      | 431      | 86     | 345      |
| July 31..... | 701     |        | 701      | 692      |        | 692      | 836     |        | 836      | 1,504    |        | 1,504    |
| Aug. 7.....  | 834     |        | 834      | 1,085    |        | 1,085    | 942     |        | 942      | 1,566    |        | 1,566    |
| Aug. 14..... | 204     |        | 204      | 442      |        | 442      | 431     |        | 431      | 750      |        | 750      |
| Total.....   | 3,543   | 344    | 3,186    | 3,233    | 189    | 3,044    | 3,794   | 532    | 3,253    | 4,884    | 367    | 4,517    |

| Date picked. | Plat 3. |        |          |          |        |          | Plat 4. |        |          |          |        |          |
|--------------|---------|--------|----------|----------|--------|----------|---------|--------|----------|----------|--------|----------|
|              | Bolls.  |        |          | Squares. |        |          | Bolls.  |        |          | Squares. |        |          |
|              | Number. | Clean. | Injured. | Number.  | Clean. | Injured. | Number. | Clean. | Injured. | Number.  | Clean. | Injured. |
| June 29..... |         |        |          | 23       | 8      | 15       |         |        |          | 48       | 12     | 36       |
| July 3.....  | 9       |        |          | 19       | 10     | 9        | 14      |        |          | 26       | 11     | 15       |
| July 10..... | 379     | 81     | 298      | 241      | 91     | 150      | 365     | 90     | 275      | 183      | 84     | 99       |
| July 17..... | 170     | 17     | 153      | 196      | 63     | 133      | 338     | 43     | 295      | 299      | 31     | 268      |
| July 25..... | 1,112   | 194    | 918      | 468      | 44     | 424      | 1,974   | 93     | 1,875    | 851      | 54     | 797      |
| July 31..... | 1,203   |        | 1,203    | 957      |        | 957      | 1,360   |        | 1,360    | 1,403    |        | 1,403    |
| Aug. 7.....  | 816     |        | 816      | 1,007    |        | 1,007    | 885     |        | 885      | 1,044    |        | 1,044    |
| Aug. 14..... | 645     |        | 645      | 1,224    |        | 1,224    | 647     |        | 647      | 843      |        | 843      |
| Total.....   | 4,334   | 292    | 4,033    | 4,135    | 216    | 3,919    | 5,583   | 232    | 5,337    | 4,697    | 192    | 4,505    |

| Date picked. | Plat 5. |        |          |          |        |          | Plat 6. |        |          |          |        |          | Average of both checks. |                 |
|--------------|---------|--------|----------|----------|--------|----------|---------|--------|----------|----------|--------|----------|-------------------------|-----------------|
|              | Bolls.  |        |          | Squares. |        |          | Bolls.  |        |          | Squares. |        |          |                         |                 |
|              | Number. | Clean. | Injured. | Number.  | Clean. | Injured. | Number. | Clean. | Injured. | Number.  | Clean. | Injured. | Bolls, total.           | Squares, total. |
| June 29..... |         |        |          | 21       | 5      | 16       |         |        |          | 65       | 16     | 49       |                         |                 |
| July 3.....  | 4       |        |          | 20       | 3      | 17       | 32      |        |          | 64       | 20     | 44       |                         |                 |
| July 10..... | 330     | 70     | 260      | 341      | 121    | 220      | 821     | 514    | 307      | 739      | 438    | 301      |                         |                 |
| July 17..... | 219     | 10     | 209      | 287      | 24     | 263      | 543     | 86     | 457      | 655      | 61     | 594      |                         |                 |
| July 25..... | 1,570   | 66     | 1,504    | 1,087    | 121    | 966      | 1,997   | 109    | 1,888    | 1,253    | 87     | 1,166    |                         |                 |
| July 31..... | 986     |        | 986      | 1,561    |        | 1,561    | 2,090   |        | 2,090    | 3,536    |        | 3,536    | 1,861                   | 3,081           |
| Aug. 7.....  | 769     |        | 769      | 1,732    |        | 1,732    | 1,177   |        | 1,177    | 2,645    |        | 2,645    | 1,233                   | 2,248           |
| Aug. 14..... | 492     |        | 492      | 1,383    |        | 1,383    | 913     |        | 913      | 2,874    |        | 2,874    | 1,032                   | 2,218           |
| Total.....   | 4,370   | 146    | 4,220    | 6,432    | 274    | 6,158    | 7,563   | 709    | 6,832    | 11,831   | 622    | 11,209   | 4,126                   | 7,547           |

TABLE 5.—*Summary of fallen forms collected from picked plats, showing percentage injured and clean, Eureka plantation, Tallulah, La., 1916.*

| Plat No.              | Bolls.        |         |           |          |           | Squares.        |         |           |          |           | Squares and bolls. |         |           |          |      |
|-----------------------|---------------|---------|-----------|----------|-----------|-----------------|---------|-----------|----------|-----------|--------------------|---------|-----------|----------|------|
|                       | Number bolls. | Clean.  |           | Injured. |           | Number squares. | Clean.  |           | Injured. |           | Total.             | Clean.  |           | Injured. |      |
|                       |               | Number. | Per cent. | Number.  | Per cent. |                 | Number. | Per cent. | Number.  | Per cent. |                    | Number. | Per cent. |          |      |
|                       |               |         |           |          |           |                 |         |           |          |           |                    |         |           |          |      |
| 1.....                | 3,543         | 357     | 10.0      | 3,186    | 89.9      | 3,233           | 189     | 5.9       | 3,044    | 94.1      | 6,776              | 546     | 7.6       | 6,230    | 92.4 |
| 2.....                | 3,794         | 541     | 14.3      | 3,253    | 85.7      | 4,884           | 367     | 7.5       | 4,517    | 92.5      | 8,678              | 908     | 10.5      | 7,770    | 89.5 |
| 3.....                | 4,334         | 301     | 7.0       | 4,033    | 93.0      | 4,135           | 216     | 5.2       | 3,919    | 94.8      | 8,469              | 517     | 6.1       | 7,952    | 93.9 |
| 4.....                | 5,583         | 246     | 4.1       | 5,337    | 95.9      | 4,697           | 192     | 4.1       | 4,505    | 95.9      | 10,280             | 438     | 4.3       | 9,842    | 95.7 |
| 5.....                | 4,370         | 150     | 3.4       | 4,220    | 96.6      | 6,432           | 274     | 4.3       | 6,158    | 95.7      | 10,802             | 424     | 4.0       | 10,378   | 96.0 |
| 6.....                | 7,563         | 731     | 9.7       | 6,832    | 90.3      | 11,831          | 622     | 5.3       | 11,209   | 94.7      | 19,397             | 1,353   | 7.0       | 18,041   | 93.0 |
| Total.....            | 29,187        | 2,326   |           | 26,861   |           | 35,212          | 1,860   |           | 33,352   |           | 64,399             | 4,186   |           | 60,213   |      |
| Weighted average..... |               |         | 7.9       |          | 92.1      |                 |         | 5.2       |          | 94.8      |                    |         | 6.5       |          | 93.5 |

TABLE 6.—*Fallen forms collected at last three collections, Eureka plantation, Tallulah, La., 1916.*

| Date.        | Plat 1. |          |        | Plat 2. |          |        | Plat 3. |          |        |
|--------------|---------|----------|--------|---------|----------|--------|---------|----------|--------|
|              | Bolls.  | Squares. | Total. | Bolls.  | Squares. | Total. | Bolls.  | Squares. | Total. |
| July 31..... | 701     | 692      | 1,393  | 836     | 1,504    | 2,340  | 1,203   | 957      | 2,160  |
| Aug. 7.....  | 834     | 1,085    | 1,919  | 942     | 1,566    | 2,508  | 816     | 1,007    | 1,823  |
| Aug. 14..... | 204     | 442      | 646    | 431     | 750      | 1,181  | 645     | 1,224    | 1,869  |
| Total.....   | 1,739   | 2,219    | 3,958  | 2,209   | 3,820    | 6,029  | 2,664   | 3,188    | 5,852  |

| Date.        | Plat 4. |          |        | Plat 5. |          |        | Plat 6. |          |        | Average check. |          |        |
|--------------|---------|----------|--------|---------|----------|--------|---------|----------|--------|----------------|----------|--------|
|              | Bolls.  | Squares. | Total. | Bolls.  | Squares. | Total. | Bolls.  | Squares. | Total. | Bolls.         | Squares. | Total. |
| July 31..... | 1,360   | 1,403    | 2,763  | 986     | 1,561    | 2,547  | 2,090   | 3,536    | 5,626  | 1,861          | 3,081    | 4,942  |
| Aug. 7.....  | 885     | 1,044    | 1,929  | 769     | 1,732    | 2,501  | 1,177   | 2,645    | 3,822  | 1,233          | 2,248    | 3,481  |
| Aug. 14..... | 647     | 843      | 1,490  | 492     | 1,383    | 1,875  | 913     | 2,874    | 3,787  | 1,032          | 2,218    | 3,250  |
| Total.....   | 2,892   | 3,290    | 6,182  | 2,247   | 4,676    | 6,923  | 4,180   | 9,055    | 13,235 | 4,126          | 7,547    | 11,673 |

Table 4 shows the plat totals of fallen forms at each of the pickings, while Table 5 shows the total collections from each of the picked plats throughout the season and indicates the percentages of clean and injured forms in each lot. In order to facilitate comparison with the checks, the last three collections of fallen forms have been isolated and summarized in Table 6, together with the check records.

From these tables it is seen that the total fallen forms collected in the picked plats throughout the season ranged from 6,776 for plat 1 to 19,397 for plat 6. Thus it is seen that about three times as many forms reached the ground in the plat picked once a week as in the plat picked six times a week.



Turning to Table 6, which includes only the last three pickings, and thus affords a comparison with the checks, it is interesting to note that the checks yielded not quite three times as many fallen forms as plat 1. In other words, bag-and-hoop pickings six times a week secured only two-thirds of the squares due to fall and allowed one-third to reach the ground. It will be noted that plat 6 yielded more fallen forms than the checks. However, this is due to the fact that the check record is an average of both checks and there was a slight grading in the soil from east to west which caused the growth and fruiting of check 1 to be more determinate than that of check 2. This resulted in a much smaller number of squares forming in check 1 this late in the season and as a result this plat lowered the check average. For this reason it is more accurate to compare plat 6 with check 2 in these last three pickings, as these two plats adjoin. Comparing in this manner it is seen that plat 6 yielded a total of 13,235 fallen forms at the last three pickings while check 2 yielded 14,342. This is a total reduction of only 1,107 fallen forms due to the once a week shaking, or an average reduction of 369 per week. In this connection it is interesting to note that the forms collected in the bags from plat 6 during those same three weeks averaged 481 per week. Totaling these figures it is seen that 14,677 forms were collected in the bags and from the ground in plat 6 during these three weeks. This is 335 more than those found on the ground in check 2. This difference in totals is practically accounted for by the fact that 290 clean forms were gathered in the bags on plat 6 during these three pickings.

In connection with these studies it is of interest to compare the total forms gathered both in the bags and from the ground in each of these plats. Table 7 shows these data for the picked plats, while Table 8 shows only the final three weeks in order to afford a comparison with the checks.

TABLE 7.—*Total forms collected in picked plats throughout season, Eureka plantation, Tallulah, La., 1916.*

| Mode of collection. | Forms collected. |         |         |         |         |         |
|---------------------|------------------|---------|---------|---------|---------|---------|
|                     | Plat 1.          | Plat 2. | Plat 3. | Plat 4. | Plat 5. | Plat 6. |
| In bags.....        | 7,015            | 6,380   | 6,068   | 4,239   | 3,166   | 2,173   |
| From ground.....    | 6,776            | 8,678   | 8,469   | 10,280  | 10,802  | 19,397  |
| Total.....          | 13,791           | 15,058  | 14,537  | 14,519  | 13,968  | 21,570  |

TABLE 8.—*Total forms collected from picked plats and checks during final 3 weeks, Eureka plantation, Tallulah, La., 1916.*

| Mode of collection. | Forms collected. |         |         |         |         |         | Average, both checks. |
|---------------------|------------------|---------|---------|---------|---------|---------|-----------------------|
|                     | Plat 1.          | Plat 2. | Plat 3. | Plat 4. | Plat 5. | Plat 6. |                       |
| In bags.....        | 3,935            | 4,369   | 4,027   | 2,847   | 2,146   | 1,442   | .....                 |
| On ground.....      | 3,958            | 6,029   | 5,852   | 6,182   | 6,923   | 13,235  | 11,673                |
| Total.....          | 7,893            | 10,398  | 9,879   | 9,029   | 9,069   | 14,677  | 11,673                |

In Table 7 it is seen that the total for the picked plats ranged from 13,791 for plat 1 to 21,570 for plat 6. However, if plat 6 is excluded, the totals are more or less approximate.

In Table 8 it is seen that for the last three weeks the totals ranged from 7,893 for plat 1 to 14,677 for plat 6. All plats totaled less than the average check except plat 6, which was 3,004 above check. Here again the soil gradation probably distorts the results somewhat, and in considering all late season results it should be remembered that the soil graded lighter from east to west and the fruiting became more determinate, so that the figures for the various plats can not be accepted absolutely at their face value. Another factor operating at this time was the effect of the shakings on plant development. This will be dealt with in detail later in the present report.

## WEEVIL INVESTIGATION.

Although the plats were so small that they could not represent, or even approximate, an actual test of weevil control under field conditions, the progress of the infestation was still followed very carefully throughout the season. This record was determined for each plat by examining 100 squares at each end and the middle of the two inside rows of the plat. This made a total of 300 squares for each plat and the percentage of these which had been weevil injured was noted. These records were made about once a week during the season. The detailed results secured are shown in Table 9.

TABLE 9.—*Weevil infestation, Eureka plantation, Tallulah, La., 1916.*

| Date.                     | Plat 1. | Plat 2. | Plat 3. | Plat 4. | Plat 5. | Plat 6. | Check 1. | Check 2. |
|---------------------------|---------|---------|---------|---------|---------|---------|----------|----------|
| June 16.....              | 8.0     | 15.0    | 6.3     | 4.6     | 0.6     | 2.6     | 9.6      | 4.3      |
| June 20.....              | 3.3     | 5.6     | 4.6     | 6.6     | 4.0     | 5.3     | 3.3      | 5.0      |
| June 27.....              | 6.6     | 4.6     | 6.6     | 5.3     | 5.3     | 7.0     | 14.0     | 10.6     |
| July 4.....               | 12.7    | 11.7    | 11.3    | 5.3     | 6.7     | 11.3    | 16.0     | 13.3     |
| July 11.....              | 7.6     | 6.6     | 4.6     | 12.6    | 19.0    | 25.0    | 28.6     | 24.6     |
| July 19.....              | 21.0    | 22.0    | 20.3    | 23.0    | 50.3    | 47.3    | 57.0     | 42.6     |
| July 26.....              | 71.3    | 64.7    | 64.7    | 68.7    | 71.3    | 76.7    | 92.0     | 84.3     |
| Aug. 2.....               | 90.0    | 83.0    | 91.0    | 94.0    | 93.3    | 90.3    | 95.7     | 94.0     |
| Aug. 9.....               | 85.3    | 85.7    | 86.7    | 89.7    | 91.3    | 88.3    | 97.3     | 94.3     |
| Aug. 15.....              | 93.3    | 94.3    | 94.7    | 97.7    | 97.0    | 97.0    | 97.7     | 97.0     |
| Average of each plat..... | 39.9    | 39.5    | 38.9    | 40.7    | 43.9    | 45.1    | 51.1     | 47.0     |

From Table 9 it is seen that a uniformly low infestation prevailed in these plats during the entire month of June, and it was not until the record of July 11 that any significant difference in the infestation of the various plats appeared. Even then the difference was rather irregular, though it showed that plats 5 and 6 and the two checks were becoming more rapidly infested than the remainder. This same condition prevailed at the examination made July 19, but by July 26 the difference had been more or less neutralized, and from that time onward the only consistent difference was the slightly higher record of the checks above the picked plats. Taking the seasonal average of the various plats, it is seen that plats 1 and 4 were practically equal, while plats 5 and 6 showed a slight increase of about 3 per cent and 5 per cent, respectively, while the two checks were slightly higher still. These figures would seem to indicate that, even in the exceedingly small plats under consideration, the pickings of three times a week or more tended to reduce the degree of weevil infestation.

#### EFFECT OF SHAKINGS ON PLANT DEVELOPMENT.

Rather early in the season it was observed that the shakings were apparently having a decidedly pronounced effect upon the growth of the plants in the various plats. It was noted that the plants in the most frequently shaken plats were apparently standing still as far as growth in height was concerned and that the more frequent the shaking the more pronounced this effect.

One method of measuring this effect was a series of studies on the average height of the plants, which was determined by measuring 20 plants in each row and taking the average. The first measurement was made on June 13, when it was found that the plants were more or less uniform in height, the range being only from 14.7 inches to 20.2 inches. At this time it was noted that the 15th to 18th rows (plats 4 and 5) were lower than the remainder. This was due to a slight dip in the land extending over these four rows, which had a tendency to retain standing water and thus somewhat retarded plant growth. This tended to reduce the average of these two plats, as will be noted in Table 10, which gives average heights of the plats and rows. Other than this slight difference the growth was very uniform over the series of plats.





FIG. 1.—TYPICAL PLANT IN PLAT 1, WITH LEAVES REMOVED, EUREKA PLANTATION, TALLULAH, LA., JULY 25, 1915. (ORIGINAL.)



FIG. 2.—TYPICAL PLANT IN CHECK 2, WITH LEAVES REMOVED, EUREKA PLANTATION, TALLULAH, LA., JULY 25, 1915. (ORIGINAL.)

COMPARISON OF SHAKEN AND UNSHAKEN COTTON PLANTS IN BOLL WEEVIL CONTROL.



FIG. 1.—LOOKING ACROSS END OF BUFFER OF PLAT 1, UNSHAKEN PLANTS ON LEFT, EUREKA PLANTATION, TALLULAH, LA., JULY 25, 1916. (ORIGINAL.)



FIG. 2.—DIVIDING LINE BETWEEN PLATS 1 AND 2, THE SHAKEN COTTON ON THE RIGHT, EUREKA PLANTATION, TALLULAH, LA., AUGUST 4, 1916. (ORIGINAL.)

COMPARISON OF SHAKEN AND UNSHAKEN COTTON PLANTS IN  
BOLL WEEVIL CONTROL.

TABLE 10.—Average height of plants in each row and plat on June 13, Eureka plantation, Tallulah, La., 1916.

| Plat number. | Row No.<br>1.  | Row No.<br>2.  | Row No.<br>3.  | Row No.<br>4.  | Plat aver-<br>age. |
|--------------|----------------|----------------|----------------|----------------|--------------------|
|              | <i>Inches.</i> | <i>Inches.</i> | <i>Inches.</i> | <i>Inches.</i> | <i>Inches.</i>     |
| 1.....       | 18.3           | 14.7           | 16.1           | 15.7           | 16.2               |
| 2.....       | 15.0           | 17.1           | 18.6           | 16.2           | 16.7               |
| 3.....       | 15.7           | 16.5           | 16.6           | 19.5           | 17.0               |
| 4.....       | 17.2           | 15.1           | 12.8           | 13.8           | 14.7               |
| 5.....       | 12.7           | 14.2           | 15.6           | 19.5           | 15.5               |
| 6.....       | 19.0           | 16.2           | 17.2           | 15.6           | 17.0               |
| Check 1..... | 19.8           | 21.4           | 20.2           | 19.5           | 20.2               |
| Check 2..... | 18.1           | 19.2           | 20.0           | 19.7           | 19.2               |

On July 15, just about one month later, similar measurements were made in these same plats and it will be seen from Table 11 that very different results were secured.

TABLE 11.—Average height of plants in each plat, Eureka plantation, Tallulah, La., 1916.

| Date measured. | Plat 1.        | Plat 2.        | Plat 4.        | Plat 4.        | Plat 5.        | Plat 6.        | Check<br>1.    | Check<br>2.    |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
|                | <i>Inches.</i> | <i>Inches.</i> | <i>Inches.</i> | <i>Inches.</i> | <i>Inches.</i> | <i>Inches.</i> | <i>Inches.</i> | <i>Inches.</i> |
| June 13.....   | 16.2           | 16.7           | 17.0           | 14.7           | 15.5           | 17.0           | 20.2           | 19.2           |
| July 15.....   | 19.8           | 23.1           | 25.4           | 25.5           | 29.2           | 34.7           | 37.4           | 44.3           |

Plat 1 was far the lowest in height, and there was a regular increase in height with the lessening in the number of shakings, the two checks being highest of all. Of course, at this time the factor of the determinate growth due to soil had become somewhat effective, and it will be noted that check 2 averaged 7 inches taller than check 1. This would tend to make the plants grade gradually in height from plat 1 to plat 6 regardless of their treatment, but the grading was far more extreme than this soil difference could explain. In fact, it will be noted that plat 6 averaged 10 inches less than check 2, which adjoined it. In the same way, plat 1 averaged 18 inches less than its adjoining check 1.

A number of photographs were taken to illustrate these differences in height of plants on July 15. Plate I, figure 1, shows a typical plant in plat 1 with the leaves removed, while figure 2 of the same plate shows a typical plant in check plat 2, thus affording a comparison of unshaken plants with those shaken six times a week. To illustrate this difference further, photographs were made showing the dividing lines between shaken and unshaken cotton. These are given in Plate II. These figures show very well the tremendous effect of the shaking operation on the height and form of the plants.

In addition to reducing the height, it was found that the shakings had considerable influence on the branching and general make-up of the plant. The most frequently shaken plants presented a bushy,



compact form with exceedingly short internodes and badly deformed stalks and branches. In addition, these frequently shaken plants were much darker in color than the others, plat 1 appearing almost blackish, in fact. This color graded off as the shakings decreased until it reached the checks, which were at that time a light-yellowish green.

At the time this plant injury was noted, examinations were made in all other tests with the use of the bag-and-hoop being conducted by the writers. These were large field plats, each some acres in extent, but it was found that wherever the bags had been used the plants presented this same deformed, dwarfed appearance, and the more frequent the use of the bags the more pronounced the injury.

The exact causes of this injurious effect of the shaking operations on the cotton plant are not positively known, but it seems probable that they are produced by several different factors. In the first place, it was noted that a very large number of terminal buds were found in the bags at all shakings, and it is probable that this loss of terminal buds was very effective in producing the bushy growth noted. The loss of the terminal bud, of course, forced the formation of adventitious buds and aided in developing the very irregular branching. In addition to this, considerable injury to the stalk itself was observed, due to the bending during the shaking operation. In shaking the plants with the bag-and-hoop, it is customary to bend the stalk near the ground at a rather sharp angle in order to insert the plant into the bag before shaking it. This apparently resulted in some crushing of the tissues at the point of bending. In extreme cases noted in the most frequently shaken plats the stalk was badly scarified at the point of bending, and in some cases was actually split for a distance of several inches.

Still another effect was probably the disturbance of the root system. Whenever the plants are shaken the movement pushes the soil away from the stalk for a distance of from 1 to 2 or 3 inches below the surface of the ground. This forms a small hole all around the stalk, and it is probable that during the formation of this hole the important lateral roots, which branch out near the surface of the ground, are either very seriously injured or actually broken off. In fact, a number of plants examined showed a decidedly distorted development at the surface of the ground.

#### SQUARE COUNTS.

Another effect of the shaking operation on the plants is shown by the square counts which were made twice during the season. For securing these records 50 plants were examined in each plat and the total and average number of squares per plant determined. The first count was made June 13, while the second was made on August 11. The results secured are shown in Table 12.

TABLE 12.—*Square counts, Eureka plantation, Tallulah, La., 1916.*

| Plat No.     | June 13.                   |                          |                              | Aug. 11.                   |                          |                              |
|--------------|----------------------------|--------------------------|------------------------------|----------------------------|--------------------------|------------------------------|
|              | Number of plants examined. | Number of squares found. | Number of squares per plant. | Number of plants examined. | Number of squares found. | Number of squares per plant. |
| 1.....       | 50                         | 689                      | 13.8                         | 50                         | 167                      | 3.3                          |
| 2.....       | 50                         | 615                      | 12.3                         | 50                         | 672                      | 13.4                         |
| 3.....       | 50                         | 679                      | 13.6                         | 50                         | 709                      | 14.2                         |
| 4.....       | 50                         | 518                      | 10.4                         | 50                         | 504                      | 10.1                         |
| 5.....       | 50                         | 568                      | 11.4                         | 50                         | 827                      | 16.5                         |
| 6.....       | 50                         | 705                      | 14.1                         | 50                         | 894                      | 17.9                         |
| Check 1..... | 50                         | 896                      | 17.9                         | 50                         | 367                      | 7.3                          |
| Check 2..... | 50                         | 688                      | 13.7                         | 50                         | 1,107                    | 22.1                         |

In the count of June 13 it was found that the plats were more or less uniform, ranging from 10.4 to 17.9 squares per plant. At this time check 1 averaged 17.9 squares per plant while check 2 averaged 13.7. Very different results were secured on August 11, when the determinate growth factor had become operative and check 1, which averaged above check 2 at the June 13 examination, averaged only 7.3 squares per plant, while check 2 averaged 22.1. In other words, the plants in check 1 had practically matured as far as their square formation was concerned, and were devoting themselves to ripening their crop of fruit. However, although check 1 averaged only 7.3 squares, plat 1 fell far lower still, averaging 3.3 squares per plant. Going to the other side of the experimental area, it is found that plat 6 averaged 17.9 squares per plant in comparison with 22.1 squares per plant in check 2. This shows the difference due to the once-a-week shakings. Owing to the soil variation it is difficult to compare the middle plats with either of the checks, but considering these outside records, which are strictly comparable, it seems obvious that the shaking operation greatly reduced the number of squares per plant, and on the whole the figures seem to warrant the conclusion that this reduction of square formation was more or less directly proportionate to the number of shakings which the plants received.

## SPACING OF PLANTS.

In order to determine if the shaking operation had had any definite effect on the stand remaining, the total number of plants in each plat was counted on July 14. The figures secured are given in Table 13.

TABLE 13.—*Average spacing on July 14—600 feet of rows in each plat, Eureka plantation, Tallulah, La., 1916.*

| Plat Number. | Number of plants in plat. | Average spacing. |
|--------------|---------------------------|------------------|
|              |                           | <i>Inches.</i>   |
| 1.....       | 349                       | 20.6             |
| 2.....       | 336                       | 21.4             |
| 3.....       | 342                       | 21.0             |
| 4.....       | 363                       | 19.8             |
| 5.....       | 332                       | 21.6             |
| 6.....       | 423                       | 17.0             |
| Check 1..... | 398                       | 18.0             |
| Check 2..... | 427                       | 16.8             |

From Table 13 it is seen that the checks averaged the closest spaced of all, while the average spacing increased somewhat as the number of shakings increased. This, of course, is undoubtedly due to the plants actually killed by the shaking operations and further illustrates the injurious effect of the bags.

## SEED-COTTON PRODUCTION.

Owing to the small size of the plats and the soil variations existing, it was not to be expected that there would be much significance in the seed-cotton production of each, but the figures were secured for whatever value they might possess. Table 14 shows the comparison of the different pickings by plats while the row results are shown in Table 15.

TABLE 14.—*Seed-cotton production; comparison of different pickings by plats, Eureka plantation, Tallulah, La., 1916.*

| Plat Number. | Seed-cotton production. |                          |                         |
|--------------|-------------------------|--------------------------|-------------------------|
|              | First picking, Aug. 17. | Second picking, Sept. 8. | Third picking, Nov. 21. |
|              | <i>Ounces.</i>          | <i>Ounces.</i>           | <i>Ounces.</i>          |
| Check 1..... | 478                     | 437                      | 42                      |
| Plat 1.....  | 189                     | 247                      | 54                      |
| Plat 2.....  | 96                      | 439                      | 145                     |
| Plat 3.....  | 285                     | 650                      | 194                     |
| Plat 4.....  | 126                     | 511                      | 108                     |
| Plat 5.....  | 166                     | 586                      | 216                     |
| Plat 6.....  | 132                     | 834                      | 217                     |
| Check 2..... | 74                      | 697                      | 391                     |



TABLE 15.—Seed-cotton production by rows and plats, Eureka plantation, Tallulah, La., 1916.

| Plat No.         | Row No. | Seed-cotton production. |                          |                         |                |                 |
|------------------|---------|-------------------------|--------------------------|-------------------------|----------------|-----------------|
|                  |         | First picking, Aug. 17. | Second picking, Sept. 8. | Third picking, Nov. 21. | Total by rows. | Total by plats. |
|                  |         | Ounces.                 | Ounces.                  | Ounces.                 | Ounces.        | Ounces.         |
| 1.....           | 1       | 68                      | 78                       | 13                      | 159            | 490             |
|                  | 2       | 55                      | 75                       | 13                      | 143            |                 |
|                  | 3       | 33                      | 36                       | 16                      | 85             |                 |
|                  | 4       | 33                      | 58                       | 12                      | 103            |                 |
| 2.....           | 5       | 20                      | 112                      | 30                      | 162            | 630             |
|                  | 6       | 15                      | 111                      | 36                      | 162            |                 |
|                  | 7       | 25                      | 99                       | 44                      | 168            |                 |
|                  | 8       | 36                      | 117                      | 35                      | 188            |                 |
| 3.....           | 9       | 71                      | 160                      | 50                      | 281            | 1,129           |
|                  | 10      | 104                     | 144                      | 50                      | 298            |                 |
|                  | 11      | 23                      | 188                      | 56                      | 267            |                 |
|                  | 12      | 87                      | 158                      | 38                      | 283            |                 |
| 4.....           | 13      | 16                      | 195                      | 33                      | 244            | 745             |
|                  | 14      | 37                      | 158                      | 26                      | 221            |                 |
|                  | 15      | 29                      | 68                       | 13                      | 110            |                 |
|                  | 16      | 44                      | 90                       | 36                      | 170            |                 |
| 5.....           | 17      | 42                      | 77                       | 28                      | 147            | 968             |
|                  | 18      | 42                      | 115                      | 32                      | 189            |                 |
|                  | 19      | 44                      | 179                      | 63                      | 286            |                 |
|                  | 20      | 38                      | 215                      | 93                      | 346            |                 |
| 6.....           | 21      | 32                      | 222                      | 67                      | 321            | 1,183           |
|                  | 22      | 28                      | 182                      | 51                      | 261            |                 |
|                  | 23      | 34                      | 204                      | 49                      | 287            |                 |
|                  | 24      | 38                      | 226                      | 50                      | 314            |                 |
| Check No. 1..... | 1       | 130                     | 94                       | 7                       | 231            | 966             |
|                  | 2       | 106                     | 133                      | 14                      | 253            |                 |
|                  | 3       | 129                     | 101                      | 7                       | 237            |                 |
|                  | 4       | 122                     | 109                      | 14                      | 245            |                 |
| Check No. 2..... | 1       | 20                      | 206                      | 65                      | 291            | 1,162           |
|                  | 2       | 18                      | 151                      | 95                      | 264            |                 |
|                  | 3       | 19                      | 164                      | 112                     | 295            |                 |
|                  | 4       | 17                      | 176                      | 119                     | 312            |                 |

A number of rather interesting points are brought out by these figures. It is seen that the picked plats generally increased in production from west to east—that is, with the decrease in pickings. Of course the increase in soil fertility is in the same direction, but it is far from sufficient to account for the differences between the plats. One break in this gradation is the comparatively low records of plats 4 and 5. This was due to the poor cotton in rows 15, 16, 17, and 18, which has already been mentioned. From Table 15 it is seen that these four rows yielded about the same as the other four rows of these two plats at the first picking, but at the second and third pickings there was a great loss in these four rows of poor cotton.

Another interesting feature of the production records is the late maturity of check 2. In this plat the vegetative growth was not restrained as in the shaken plats, and as a result the exceedingly wet weather of July produced a very rank plant which shaded the bolls so completely that they did not open. From Table 14 it is seen that this plat yielded far the lowest of all at the first picking, and it was not until the leaves were killed by the frost that a good portion of the crop in this plat finally opened. In fact, a considerable proportion

of the bolls in check 2 never opened, as they rotted while covered with the dense foliar growth. Thus it is seen that the detrimental effect of the shaking on the fruiting of plat 6 was offset by the reduced vegetative growth (due to this same shaking), allowing a greater proportion of the bolls to open safely, and thus actually yielding more cotton than check 2, although check 2 set more bolls than plat 6. However, in a normal season this rank growth and the accompanying boll rot would not be encountered, and consequently somewhat different results would undoubtedly be secured.

In order to avoid repetition the summary of this series of studies is included in the general discussion at the end of the present report.

#### **PLAT TESTS OF THE VALUE OF THE BAG-AND-HOOP AS A MEANS OF WEEVIL CONTROL UNDER FIELD CONDITIONS.**

During the season of 1916 two series of tests were conducted to determine the value of the bag-and-hoop as a means of weevil control on the plantation. One of these tests was conducted on Hecla plantation at Mound, La., and consisted of a study of five pickings at weekly intervals on Express cotton. The principal idea of this test was to secure data on this variety of cotton, as all of the earlier work had been with the Simpkins variety and no records had been secured on the result of using the bag-and-hoop on a long-staple cotton. It was expected that there would be some difference in results between the long and short staple cottons, especially in the number of forms collected during the pickings. The long-staple cottons generally tend to retain the infested forms longer than do the short varieties, and, consequently, it seemed probable that a different proportion of the infested forms would be gathered while shaking the staple cotton.

The second test was conducted on Eureka plantation and consisted of a study of varying numbers of pickings at different time intervals on Simpkins cotton. This test is referred to as Eureka test No. 1 in order to distinguish it from the studies just described.

#### **EXPERIMENT ON HECLA PLANTATION.**

For conducting this test on Hecla plantation a small cut of cotton some 4 acres in extent was selected. This cut was comparatively new land, which had been in corn for several years and immediately adjoined heavy timber. The cotton immediately adjoining the woods consisted of a number of irregular short rows, and these were omitted from the plat, the first row of the plat proper being the third row, which extended completely through the cut. However, in order to protect the picked plat from an influx of weevils, these short rows of cotton between this plat and the timber were picked over every time the plat was picked, and in the same manner the ends of the

rows extending beyond the plat lines of the picked plat were shaken each time for further protection. A buffer system was also instituted between the two plats to reduce as far as possible the influence that either plat might have on the other. This system consisted of dropping four rows from each plat immediately adjoining the dividing line when considering the plat production. As treated throughout the season the plats consisted of 22 rows each, or an area of 1.44 acres. With the four-row buffer dropped from each plat, however, the plats proper each consisted of 18 rows with an area of 1.18 acres.

The soil was of a rather heavy "buckshot" type. The drainage was fair over most of the plats, but a low area which extended across the center of both plats was rather poorly drained. The outer two rows of the check plat immediately adjoining the roadside ditch were also lower than the remainder of the plat, especially at the eastern end. In an ordinary season this difference in drainage would have made little difference in the plats, but the summer of 1916 was so exceedingly wet that the slightest difference in drainage was greatly accentuated. As a result a narrow strip across the middle of the picked plat and a wider strip through the check, as well as a considerable area in the southeast corner of the check plat, suffered from an excess of water. This tended to throw the plats "off balance," as a much greater area in the check was injured than in the picked plat. This fact of course should be borne in mind in considering the results secured.

#### PICKINGS.

The idea of this test was to start the pickings as soon as the weevils became sufficiently abundant to make the operation worth while. In order to determine this time, regular examinations were made at different points throughout the plats, beginning with May 8. On this date 2,100 plants were examined, and no weevils were found. On May 13, one thousand plants yielded eight weevils, but on the 19th the same number yielded four weevils. On May 24, twelve weevils were found on 1,000 plants. These records were made in belts extending along the plats parallel to the timber line. After this time, however, separate records were secured for the two plats. The observations were made at both ends and the middle of each plat. In the examination of June 1 it was found that plat 1 averaged one weevil to 55 plants, while plat 2 averaged one weevil to 33 plants. On June 5 both plats averaged one weevil to 75 plants. From these observations it is seen that a fairly heavy infestation was being developed rather gradually in this field, and it was not until the middle of June that a considerable increase in the number of weevils was noted. Consequently, the plat was first picked over on June 16, at which time 129 weevils per acre were collected. This



was a rather large number and is apparently due to a sudden emergence of a great number of weevils at about this time. This plat was picked five times in all on the following dates, June 16, 22, 29, July 10 and 17. This made the pickings extend over a total period of 32 days, the average time interval being eight days.

At the time of the first picking the stage of plant development was determined by a series of square counts and plant-height measurements distributed over the two plats. From these it was found that there was an average of 3.1 squares per plant and the average height of the plants was 11.4 inches at this time.

The time required to make the various pickings is shown in Table 16.

TABLE 16.—*Labor involved in weevil picking; Hecla plantation experiment, Mound, La., 1916.*

| Date.        | Area.         | Per plat.     |                                     | Per acre:     |                                     |
|--------------|---------------|---------------|-------------------------------------|---------------|-------------------------------------|
|              |               | Hours, labor. | Cost of labor at 7½ cents per hour. | Hours, labor. | Cost of labor at 7½ cents per hour. |
|              | <i>Acres.</i> |               |                                     |               |                                     |
| June 16..... | 1.44          | 7.5           | \$0.56                              | 5.2           | \$0.39                              |
| June 22..... | 1.44          | 4.5           | .34                                 | 3.1           | .24                                 |
| June 29..... | 1.44          | 8.0           | .60                                 | 5.6           | .42                                 |
| July 10..... | 1.44          | 7.0           | .53                                 | 4.9           | .37                                 |
| July 17..... | 1.44          | 9.0           | .68                                 | 6.2           | .47                                 |
| Total.....   |               | 36.0          | 2.71                                | 25.0          | 1.89                                |
| Average..... |               |               |                                     | 5.0           | .38                                 |

Both men and women were used for this purpose, and as the work was about equally divided between the two the value of the labor is figured at the rate of 7½ cents an hour, which represents a fair average. From this table it is seen that an average of five hours per acre was required for each picking. Figuring on the basis of a 10-hour day this would mean 2 acres per day per hand on the average. This is a slightly higher average than has been secured from most of the figures on area covered per hand per day and is probably due to the fact that with the number of hands used and the small size of the plats only a few hours were required for the picking. It is quite probable that the laborers would not have maintained this same rate of speed if they had been working all day. The cost figures show an average of 38 cents per acre per picking, or a total of \$1.89 per acre for the five pickings.

In connection with these same labor observations, a comparison was made of the relative efficiency of different individuals. Three men were selected, two of whom were fast workers and the third a very slow hand. Separate records were kept of these individuals while the fast hands were covering eight rows each and the slow

man picked six. It was found that while the fast men took much less time for a row than the slow one, they averaged 8.1 and 10.9 weevils to the row, whereas the slow one averaged only 4. Thus it is seen that the efficiency of the individual largely determines not only the speed of the operation, but also its thoroughness. This same observation has been made a number of times and it was found that the individuals varied even more widely than the figures just given would indicate.

The weevils collected at the various pickings are shown in Table 17.

TABLE 17.—*Weevils collected with bag-and-hoop, Hecla plantation experiment, Mound, La., 1916.*

| Picking.    | Date.   | Number weevils collected. | Weevils per acre. |
|-------------|---------|---------------------------|-------------------|
| First.....  | June 16 | 185                       | 129               |
| Second..... | June 22 | 178                       | 124               |
| Third.....  | June 29 | 160                       | 111               |
| Fourth..... | July 10 | 159                       | 110               |
| Fifth.....  | July 17 | 163                       | 113               |
| Total.....  |         | 847                       | 587               |

From this it is seen that the pickings ranged from 110 to 129 weevils per acre, with a total of 587 weevils per acre for the five pickings. It is interesting to note that the highest number was collected at the first picking. The range, however, was comparatively small.

The forms collected in the bag-and-hoop are shown in Table 18.

TABLE 18.—*Forms collected per acre with bag-and-hoop, Hecla plantation experiment, Mound, La., 1916.*

| Date.                 | Forms collected per acre. |        |            | Clean.                  | Punctured.               |
|-----------------------|---------------------------|--------|------------|-------------------------|--------------------------|
|                       | Total.                    | Clean. | Punctured. |                         |                          |
| June 16.....          | 285                       | 17     | 268        | <i>Per cent.</i><br>5.8 | <i>Per cent.</i><br>94.2 |
| June 22.....          | 346                       | 45     | 301        | 13.1                    | 86.9                     |
| June 29.....          | 414                       | 59     | 355        | 14.3                    | 85.7                     |
| July 10.....          | 894                       | 355    | 539        | 39.8                    | 60.2                     |
| July 17.....          | 506                       | 139    | 367        | 27.6                    | 72.4                     |
| Total.....            | 2,445                     | 615    | 1,830      |                         |                          |
| Weighted average..... |                           |        |            | 25.2                    | 74.8                     |

At the first three pickings only squares were secured, but at the fourth and fifth both squares and bolls were collected. A total of 2,445 forms were collected at the five pickings, of which 1,830 were punctured and 615 were clean. Thus it is seen that practically one-fourth of the forms collected in the bag-and-hoop were clean. While making these collections it was noted also that a considerable number of terminal buds were broken off and gathered in the sacks.

In order to see if these injured forms collected in the bags were reducing the number reaching the ground to any extent, one collection of fallen forms was made in both plats on July 14. For this purpose a strip 20 feet long and three rows wide was laid off in the middle and each end of each plat, and all fallen forms were gathered from these strips. As the rows averaged four and a half feet in width, the total area examined in each plat was 820 square feet. The strips were selected so that no skips in stand were included, and the cotton as nearly as possible represented the average growth of that portion of the plat. As the preceding bag-and-hoop collection had been made on July 10, this fallen form collection was four days after a picking. The results secured are shown in Table 19.

TABLE 19.—*Fallen forms collected in Hecla plantation experiment, Mound, La., July 14, 1916.*

| Plat.       | Forms gathered. |        |        |
|-------------|-----------------|--------|--------|
|             | Squares.        | Bolls. | Total. |
| Check.....  | 447             | 23     | 470    |
| Picked..... | 234             | 21     | 255    |

From Table 19 it is seen that while the boll collection differed very little, there were 213 more squares collected from the check than from the picked plat. If these figures are taken as a criterion, they show that the bag-and-hoop pickings reduced the forms reaching the ground by 47 per cent. This is a considerably greater reduction than has been found in most of the tests with the 7-day interval, but this difference may well be due to the varietal differences in the cotton. As has already been mentioned, this test was conducted with a long-staple variety which tended to retain a considerable proportion of the infested squares. Even the squares which were going to fall were probably sufficiently attached to the plant to remain somewhat longer than would be the case on a short-staple variety, and consequently their chance of being collected in the bags was increased.

One important question in connection with this type of plat work concerns the influence of one plat upon another and also the influence of any near-by untreated cotton on the treated plat. This point, of course, is of primary importance in determining just how nearly such plat tests represent the conditions which would prevail if an entire field was treated in the same manner as the plat in question. In an effort to secure some information on this point the records of the bag-and-hoop collections of weevils and forms were made by rows as well as by plats. The rows in the picked plat were numbered from 1 to 22, beginning with the row adjoining the check, and the record for each row was kept separate throughout the five pickings.



TABLE 20.—Row records of weevils collected with bag-and-hoop, Hecla plantation experiment, Mound, La., 1916.

| Row No. | Weevils collected. |          |          |          |          |            |                                               | Average per row outside and inside blocks. |
|---------|--------------------|----------|----------|----------|----------|------------|-----------------------------------------------|--------------------------------------------|
|         | June 16.           | June 22. | June 29. | July 10. | July 17. | Row total. | Average per row in 5-row blocks. <sup>1</sup> |                                            |
| 1.....  | 8                  | 7        | 4        | 8        | 17       | 44         | 43.3                                          | 43.3                                       |
| 2.....  | 5                  | 7        | 4        | 5        | 7        | 28         |                                               |                                            |
| 3.....  | 8                  | 12       | 2        | 14       | 11       | 47         |                                               |                                            |
| 4.....  | 9                  | 14       | 18       | 8        | 8        | 57         |                                               |                                            |
| 5.....  | 9                  | 16       | 5        | 5        | 6        | 41         |                                               |                                            |
| 6.....  | 10                 | 6        | 14       | 5        | 8        | 43         | 42.0                                          | 39.0                                       |
| 7.....  | 6                  | 1        | 7        | 6        | 13       | 33         |                                               |                                            |
| 8.....  | 8                  | 8        | 6        | 13       | 10       | 45         |                                               |                                            |
| 9.....  | 6                  | 2        | 10       | 7        | 8        | 33         |                                               |                                            |
| 10..... | 25                 | 11       | 8        | 11       | 8        | 63         |                                               |                                            |
| 11..... | 8                  | 14       | 5        | 5        | 4        | 36         | 36.0                                          | 32.5                                       |
| 12..... | 6                  | 5        | 5        | 12       | 8        | 36         |                                               |                                            |
| 13..... | 14                 | 6        | 3        | 7        | 4        | 34         |                                               |                                            |
| 14..... | 3                  | 14       | 14       | 5        | 6        | 42         |                                               |                                            |
| 15..... | 4                  | 2        | 8        | 8        | 7        | 29         |                                               |                                            |
| 16..... | 9                  | 5        | 12       | 6        | 7        | 39         | 32.5                                          | 32.5                                       |
| 17..... | 8                  | 10       | 0        | 3        | 9        | 30         |                                               |                                            |
| 18..... | 2                  | 9        | 2        | 5        | 3        | 21         |                                               |                                            |
| 19..... | 13                 | 11       | 9        | 7        | 9        | 49         |                                               |                                            |
| 20..... | 4                  | 6        | 4        | 6        | 3        | 23         |                                               |                                            |
| 21..... | 11                 | 7        | 9        | 3        | 5        | 35         | 37                                            |                                            |
| 22..... | 9                  | 5        | 11       | 10       | 2        | 37         |                                               |                                            |

<sup>1</sup> Outside blocks each consist of 6 rows.

The weevil collection records are shown in Table 20. Owing to the variations produced by the individual efficiency of the pickers, it does not seem advisable to compare the various rows at a single picking, but this factor should be more or less averaged out in the five pickings, and to reduce this error further the rows have been averaged together in blocks. It will be noted that the first average of this type divides the plat into four blocks, the outside blocks consisting of six rows each and the two inside blocks consisting of five rows each. From this grouping it is seen that rows 1 to 6 averaged 43.3 weevils per row, while rows 7 to 11 averaged 42; rows 12 to 16 averaged 36 and rows 17 to 22 averaged 32.5. Thus it is seen that there is a more or less regular decrease in the infestation of the picked plat as the distance from the check plat is increased. However, the highest record for any single row was row 10, which was very nearly in the center of the plat. These figures would seem to indicate that picking cotton beyond the ends of the picked plat and to the north of it prevented the plat from receiving an infestation of weevils from those sides. It is also seen that there was apparently some migration of weevils from the check plat into the south side of the picked plat. However, this was not of grave importance and is probably largely counteracted by the later omission of rows 1 to 4 as buffers.

TABLE 21.—Row records of infested squares collected with bag-and-hoop, *Hecla* plantation experiment, Mound, La., 1916.

| Row No. | Infested squares collected. |          |          |          |          |            | Average per row in 5-row blocks. <sup>1</sup> | Average per row of outside and inside blocks. |
|---------|-----------------------------|----------|----------|----------|----------|------------|-----------------------------------------------|-----------------------------------------------|
|         | June 16.                    | June 22. | June 29. | July 10. | July 17. | Row total. |                                               |                                               |
| 1.....  | 22                          | 23       | 19       | 47       | 71       | 182        | 144.0                                         | 144.0                                         |
| 2.....  | 8                           | 14       | 19       | 33       | 40       | 114        |                                               |                                               |
| 3.....  | 13                          | 28       | 6        | 5        | 43       | 95         |                                               |                                               |
| 4.....  | 32                          | 29       | 36       | 23       | 29       | 196        |                                               |                                               |
| 5.....  | 13                          | 12       | 23       | 36       | 38       | 122        | 127.0                                         | 118.8                                         |
| 6.....  | 18                          | 11       | 28       | 64       | 33       | 154        |                                               |                                               |
| 7.....  | 19                          | 19       | 27       | 31       | 18       | 114        |                                               |                                               |
| 8.....  | 28                          | 26       | 15       | 48       | 30       | 147        |                                               |                                               |
| 9.....  | 13                          | 8        | 28       | 19       | 14       | 82         | 110.6                                         | 83.1                                          |
| 10..... | 25                          | 33       | 24       | 48       | 24       | 154        |                                               |                                               |
| 11..... | 44                          | 28       | 35       | 26       | 4        | 137        |                                               |                                               |
| 12..... | 8                           | 18       | 14       | 28       | 23       | 91         |                                               |                                               |
| 13..... | 24                          | 23       | 22       | 44       | 11       | 124        | 83.1                                          | 83.1                                          |
| 14..... | 15                          | 18       | 29       | 29       | 18       | 109        |                                               |                                               |
| 15..... | 10                          | 23       | 21       | 26       | 16       | 96         |                                               |                                               |
| 16..... | 24                          | 23       | 51       | 26       | 9        | 133        |                                               |                                               |
| 17..... | 9                           | 18       | 19       | 11       | 20       | 77         | 83.1                                          | 83.1                                          |
| 18..... | 9                           | 23       | 11       | 30       | 13       | 86         |                                               |                                               |
| 19..... | 18                          | 22       | 20       | 22       | 14       | 96         |                                               |                                               |
| 20..... | 14                          | 16       | 19       | 44       | 2        | 95         |                                               |                                               |
| 21..... | 9                           | 20       | 30       | 7        | 12       | 78         | 67                                            |                                               |
| 22..... | 12                          | 12       | 15       | 23       | 5        | 67         |                                               |                                               |

<sup>1</sup> Outside blocks each consist of 6 rows.

Table 21 shows the row collections of the infested squares in the same manner. An analysis of this table by blocks shows the square collections to correlate very well with the weevil collections, the number of infested squares decreasing with the increase in distance from the check plat. In this connection it is interesting to note that the highest record was in row 4, while the second highest was in row 1, so it is seen that the most highly infested rows were included in the 4-row buffer which was dropped.

Considering these row records on the whole it is seen that the only outside influence affecting the infestation of the picked plat was apparently the migration of the weevils from the check plat. This was sufficient in extent to increase slightly the infestation of the side immediately adjoining the check and would undoubtedly have some influence on the results secured. However, this migration appears to have been comparatively unimportant, and consequently its only effect on the results would be in the degree. That is, it would not offset any beneficial effect from the bag-and-hoop collections, but probably would lessen the gain somewhat.

## INFESTATION.

The infestation of these various plats was followed throughout the season in the usual manner. As has been mentioned, the weevil abundance was determined from May 8 to June 5 by plant examinations, the figures secured expressing the ratio of the weevils to the plants. After June 5, however, the squares became sufficiently

abundant to allow square-infestation records. This type of record was begun on June 15 and continued at weekly intervals until August 9. At the first three examinations 100 squares were examined in each corner and the center of each plat, making a total of 500 squares to the plat. Beginning with July 4, however, the records were made in the center of each end and the middle of each plat, 200 squares being examined at each point, making a total of 600 squares to the plat.

Table 22 shows the figures secured at these examinations.

TABLE 22.—*Weevil infestation, Hecla plantation experiment, Mound, La., 1916.*

| Date of examination.   | Infestation.     |                  |
|------------------------|------------------|------------------|
|                        | Picked plat.     | Check plat.      |
|                        | <i>Per cent.</i> | <i>Per cent.</i> |
| June 15.....           | 65.6             | 49.0             |
| June 20.....           | 43.8             | 47.8             |
| June 27.....           | 34.0             | 38.6             |
| July 4.....            | 39.0             | 25.5             |
| July 10.....           | 25.7             | 24.7             |
| July 17.....           | 47.0             | 50.2             |
| July 26.....           | 48.2             | 53.2             |
| Aug. 1.....            | 71.0             | 67.8             |
| Aug. 9.....            | 87.8             | 89.8             |
| Weighted averages..... | 51.5             | 49.9             |

From Table 22 it is seen that there was no significant regularity in the comparative infestation of the two plats. In fact, in the weighted average for the season there was a difference of only 1.6 per cent in the infestation of the two plats. These infestation records failed to show any effect whatever from the pickings, as there was no apparent reduction in the infestation of the picked plat at any time.

Averages of the infestation records at each of the points of observation throughout the season give the following:

| Picked plat:  | <i>Per cent.</i> |
|---------------|------------------|
| West end..... | 54.4             |
| Center.....   | 47.4             |
| East end..... | 52.1             |
| Check plat:   |                  |
| West end..... | 49.4             |
| Center.....   | 50.8             |
| East end..... | 49.2             |

From these averages it is seen that the infestation was very evenly distributed over the two plats, as the extreme range was only from 47.4 per cent to 54.4 per cent. It is interesting to note that both of these extremes were located in the picked plat. The averages at the points where the infestation was determined are further evidence of the failure of the picking operation to reduce the weevil infestation in the picked plat.



## EFFECT ON PLANTS.

After the first few shakings it was noticed that this operation was having a decided effect on the growth of the plants. The shaken plants were becoming much shorter than the check plants and were more bushy and compact in growth. This became so pronounced that on August 1 the height of 200 plants in each end and the center of each plat was measured. These 600 plants in the picked plat averaged 48.6 inches in height, while those in the check plat averaged 58.6 inches in height. Thus the plants in the check plat averaged 10.3 inches higher than those in the picked.

## BOLL COUNTS.

In order to secure some index to the fruit being set in these two plats, 100 plants were examined in each end of each plat on July 17 and the bolls counted. At this time it was found that the picked plat averaged 3.9 bolls to the plant, while the check plat averaged 5.4 bolls to the plant. These observations were checked very carefully by a thorough examination of both plats, and it seemed obvious that the check plat, generally speaking, was fruiting better than the picked plat. However, the factor of drainage had become operative at this time, and it was seen that portions of the check plat were injured seriously by the drowning of the plants in poorly drained areas.

## PRODUCTION.

The seed cotton matured in these plats was picked on October 30. The amounts secured are shown in Table 23.

TABLE 23.—Seed-cotton production in Hecla plantation test, Mound, La., 1916.

| Plat and treatment. | Area.         | Seed-cotton production. |                |
|---------------------|---------------|-------------------------|----------------|
|                     |               | Per plat.               | Per acre.      |
|                     | <i>Acres.</i> | <i>Pounds.</i>          | <i>Pounds.</i> |
| 1. Picked.....      | 1.18          | 591                     | 501            |
| 2. Check.....       | 1.18          | 541                     | 458            |

From Table 23 it is seen that the picked plat exceeded the check in production by 43 pounds of seed cotton per acre. This was a gain of 9 per cent over the check. At first glance this result seems rather surprising in view of the result of the boll counts and other observations made on the relative fruiting of the two plats, which showed the check plat to be leading the picked plat by a considerable margin. In fact, the boll count showed the check plat to have a 38 per cent margin over the picked plat. Of course, such boll counts are not absolutely accurate, but they usually prove fairly representative. However,

other factors than the weevil picking itself were operating to influence the production of these two plats. The factor of drainage has been mentioned as seriously injuring a portion of the check plat. In fact, this injury probably was sufficient practically to account for the results secured. In addition to this, the factor of boll rot must be considered. The exceedingly wet weather of July caused an excessively rank plant growth on all highly nitrogenous land, such as that on which these plats were located, and this resulted in the rotting of many of the lower bolls which could not be reached by the sunlight. It has been shown that, while the shaking operations were reducing the fruiting of the plants, they also tended to prevent a rank plant development. As a result, there was little or no boll rot in the picked plat, while the check was injured seriously by this factor. Consequently it is seen that, while the shaking operation actually reduced the fruit set in the picked plat, the reduction in foliar development served to offset this by preventing boll rot.

Taking these two factors of boll rot and poor drainage of the check plat into consideration, it is possible to understand why the check matured less cotton than the picked plat in spite of the fact that it actually set more bolls per plant on the poorly drained portions of the plat. To check the production record a bur count was made in both plats by examining 500 plants in each on October 31. At this time it was found that the check plat averaged 7.4 burs per plant, while the picked plat averaged 8.7 per plant. Thus it is seen that the bur count corresponded fairly well with the production record of the two plats. This tends to place further emphasis on the probable accuracy of the boll count.

At any rate, regardless of the explanation of the weights secured, the fact remains that the difference in favor of the picked plat was so small as to constitute an economic loss, and the utter absence of evidence of a reduction of the infestation of the picked plat due to the pickings makes this test decidedly unfavorable to weevil picking as a means of control.

#### EUREKA PLANTATION EXPERIMENT NO. 1.

The more extensive Eureka test was located in a cut of cotton extending along Walnut Bayou. The series consisted of five plats, each plat extending at right angles to the bayou. The soil on which these plats were located was a rather light sandy loam on the bayou front, grading off heavier toward the back of the cut. As practically all soil gradation in this cut was from north to south, and as it was fairly uniform from east to west, the plats should have been reasonably comparable as regards the soil, since each extended through the extreme variation. To safeguard further against soil variations two check plats were selected, one on the east side of the series and

the other on the west. In most cases in the following report the average of the records made on these two check plats is given instead of the individual records of the two, as this average should compare best with the conditions existing between the two checks. Three treated plats were arranged between these two check plats. The first of these, plat 2, was picked once a week for six weeks; plat 3 was picked twice a week for six pickings, while plat 4 was picked once a week for four weeks.

As considered during the period of treatment, each plat was 22 rows in width and 380 feet long. This made the area of each plat exactly 1 acre. However, it was recognized that there would probably be some interplat effect at the dividing lines, so a buffer system was arranged between each two plats at the time of picking in order to absorb as much as possible of this interplat effect. This system consisted of omitting four rows on each side of each dividing line. As the checks adjoined plats on only one side, this resulted in four rows being dropped from each check, while eight rows were dropped from each picked plat. Thus the checks finally considered consisted of 0.82 of an acre each, while the picked plats each consisted of 0.64 of an acre. However, all figures given in the present report, with the exception of those of production, are based on plats of 1 acre each, and, of course, the production was reduced to an acreage basis. In order to protect the plats further from outside influence a buffer system across the ends of the picked plats was maintained throughout the picking period. For this purpose the pickings were extended about 30 feet beyond the plat lines at each end each time a plat was picked.

This cut was planted in corn and peas during 1915, and a very heavy growth was turned under. This resulted in the land being in excellent condition with the exception of a rather spotted infestation of nut-grass extending along the back of the cut. However, the back end of the plats was moved forward sufficiently to avoid this grassy area almost entirely. The drainage throughout all plats was very good, and there was no apparent water injury at any time, in spite of the excessive rains during July. The cotton was the Simpkins Ideal variety, which had been planted on April 5. A very good stand was secured over all the plats.

#### PICKINGS.

As in the case of the Hecla experiment, the idea was to begin the pickings as soon as the weevils became sufficiently abundant to make the operation worth while. Plant-infestation studies were made in the same manner as those already described for Hecla plantation. On May 10, 1,000 plants were examined and no weevils found; on May 17 three weevils were found on 1,000 plants, while on May 23 one



weevil was found, and on May 30, two weevils were found to 1,000 plants. On June 6 the plant examinations were separated by plats and 50 plants were examined in each end and the center of each plat, making a total of 150 plants to the plat. At this time only two weevils were found, one in plat 1 and one in plat 3. From these figures it is seen that the emergence of weevils into these plats was exceedingly light and late. However, by about June 12 a rather heavy general emergence of weevils was taking place over the parish, and it was considered advisable to begin picking these plats, in spite of the fact that only a small number of weevils had been found in this cut. Consequently, the first picking of all of the plats was made on June 13. At this time plat 2 yielded 10 weevils to the acre, plat 3 yielded 13, and plat 4 yielded 6. This is quite different from the first picking made three days later on Hecla plantation, when 129 weevils per acre were collected, and shows the light initial infestation of this series of plats.

In order to determine the exact stage of the cotton plants at the time of this first picking the squares were counted on 20 plants at 10 different points in the series of plats. These 200 plants averaged 7.5 squares per plant. A similar study of the plant heights showed them to average 13.1 inches at this time.

The labor involved in these pickings is shown in Table 24, figured on the same basis as in the Hecla test.

TABLE 24.—*Labor required for picking weevils, Eureka plantation, Tallulah, La., 1916, experiment No. 1.*

| Plat No. | Picking.     | Date.   | Labor per acre. | Cost of labor per acre, at 7½ cents per hour. |
|----------|--------------|---------|-----------------|-----------------------------------------------|
| 2.....   |              |         | <i>Hours.</i>   |                                               |
|          | First.....   | June 13 | 6.4             | \$0.48                                        |
|          | Second.....  | June 20 | 5.5             | .41                                           |
|          | Third.....   | June 27 | 6.0             | .45                                           |
|          | Fourth.....  | July 5  | 9.0             | .68                                           |
|          | Fifth.....   | July 11 | 15.0            | 1.13                                          |
|          | Sixth.....   | July 22 | 10.0            | .75                                           |
|          | Total.....   |         | 51.9            | 3.90                                          |
|          | Average..... |         | 8.6             | .65                                           |
|          |              |         |                 |                                               |
| 3.....   | First.....   | June 13 | 6.4             | .48                                           |
|          | Second.....  | June 17 | 4.5             | .34                                           |
|          | Third.....   | June 20 | 5.5             | .41                                           |
|          | Fourth.....  | June 23 | 6.5             | .49                                           |
|          | Fifth.....   | June 27 | 6.0             | .45                                           |
|          | Sixth.....   | June 30 | 8.0             | .60                                           |
|          | Total.....   |         | 36.9            | 2.77                                          |
|          | Average..... |         | 6.1             | .46                                           |
|          |              |         |                 |                                               |
|          |              |         |                 |                                               |
| 4.....   | First.....   | June 13 | 6.4             | .48                                           |
|          | Second.....  | June 20 | 5.5             | .41                                           |
|          | Third.....   | June 27 | 6.0             | .45                                           |
|          | Fourth.....  | July 5  | 9.0             | .68                                           |
|          | Total.....   |         | 26.9            | 2.02                                          |
|          | Average..... |         | 6.7             | .51                                           |

From this it is seen that the cost per acre ranged from 46 to 65 cents for picking in the different plats. Of course, the average per picking increases as the season progresses, and consequently the greater number of pickings cost more per picking. The hours of labor per acre ranged from 6.1 to 8.6. From the total cost figures it is seen that the four pickings at an interval of one week cost \$2.02, while 6 pickings at the same time interval cost \$3.90. The six pickings given twice a week cost \$2.77. These records show a uniformly higher cost for the pickings on Eureka than on Hecla, and, judging from the general observations which have been made, it is probable that the Eureka figures more nearly represent average conditions.

The weevils collected from these plats at the various pickings are shown in Table 25.

TABLE 25.—*Weevils collected per acre with bag-and-hoop, Eureka plantation, Tallulah, La., 1916, experiment No. 1.*

| Plat No. | Picking.    | Date.   | Number of weevils collected. |
|----------|-------------|---------|------------------------------|
| 2.....   | First.....  | June 13 | 10                           |
|          | Second..... | June 20 | 11                           |
|          | Third.....  | June 27 | 25                           |
|          | Fourth..... | July 5  | 63                           |
|          | Fifth.....  | July 11 | 82                           |
|          | Sixth.....  | July 22 | 470                          |
|          | Total.....  |         | 661                          |
| 3.....   | First.....  | June 13 | 13                           |
|          | Second..... | June 17 | 11                           |
|          | Third.....  | June 20 | 6                            |
|          | Fourth..... | June 23 | 13                           |
|          | Fifth.....  | June 27 | 27                           |
|          | Sixth.....  | June 30 | 20                           |
|          | Total.....  |         | 90                           |
| 4.....   | First.....  | June 13 | 6                            |
|          | Second..... | June 20 | 9                            |
|          | Third.....  | June 27 | 27                           |
|          | Fourth..... | July 5  | 43                           |
|          | Total.....  |         | 85                           |

From Table 25 it is seen that if the sixth picking in plat 2 is excluded, the highest number of weevils collected per acre at any picking was 82. However, there was a tremendous increase at the sixth picking of plat 2, and 470 weevils per acre were collected at this time. This increase was due to the effect of climatic conditions on the multiplication of the weevils. As has been mentioned, the month of July was exceedingly rainy, the plats being subjected to a shower almost every day in the month. This, of course, produced a great reduction in the climatic control of the weevils in the fallen forms and, as a result, although the initial infestation of these plats was very light, the July-bred weevils multiplied so rapidly that this was quickly changed to an excessively heavy infestation. Considering the totals collected from

the various plats, it is seen that only 85 weevils were secured from plat 4, while 90 were picked from plat 3. The high number secured at the sixth picking brought the total for plat 2 up to 661.

The forms collected in the bags from the different plats at the various pickings are shown in Table 26.

TABLE 26.—Forms collected per acre with bag-and-hoop, Eureka plantation, Tallulah, La., 1916, experiment No. 1.

| Plat No. | Date.                 | Forms collected. |        |            | Clean.                   | Punctured.               |
|----------|-----------------------|------------------|--------|------------|--------------------------|--------------------------|
|          |                       | Total.           | Clean. | Punctured. |                          |                          |
| 2.....   | June 13.....          | 123              | 48     | 75         | <i>Per cent.</i><br>39.0 | <i>Per cent.</i><br>61.0 |
|          | June 20.....          | 116              | 43     | 73         | 37.1                     | 62.9                     |
|          | June 27.....          | 338              | 159    | 179        | 47.0                     | 53.0                     |
|          | July 5.....           | 472              | 271    | 201        | 57.4                     | 42.6                     |
|          | July 11.....          | 1,309            | 990    | 319        | 75.6                     | 24.4                     |
|          | July 22.....          | 2,196            | 419    | 1,777      | 19.1                     | 80.9                     |
|          | Total.....            | 4,554            | 1,930  | 2,624      |                          |                          |
|          | Weighted average..... |                  |        |            | 42.4                     | 57.6                     |
|          | June 13.....          | 108              | 33     | 75         | 30.6                     | 69.4                     |
|          | June 17.....          | 156              | 68     | 88         | 43.6                     | 56.4                     |
| 3.....   | June 20.....          | 127              | 43     | 84         | 33.9                     | 66.1                     |
|          | June 23.....          | 83               | 42     | 41         | 50.6                     | 49.4                     |
|          | June 27.....          | 231              | 105    | 125        | 45.5                     | 54.5                     |
|          | June 30.....          | 223              | 109    | 114        | 48.9                     | 51.1                     |
|          | Total.....            | 928              | 400    | 528        |                          |                          |
|          | Weighted average..... |                  |        |            | 43.1                     | 56.9                     |
| 4.....   | June 13.....          | 76               | 28     | 48         | 36.8                     | 63.2                     |
|          | June 20.....          | 98               | 25     | 73         | 25.5                     | 74.5                     |
|          | June 27.....          | 223              | 99     | 124        | 44.4                     | 55.6                     |
|          | July 5.....           | 330              | 224    | 106        | 67.9                     | 32.1                     |
|          | Total.....            | 727              | 376    | 351        |                          |                          |
|          | Weighted average..... |                  |        |            | 51.7                     | 48.3                     |

One interesting feature of the figures shown in Table 26 is the extremely rapid increase in the number of forms collected at the later pickings. For example, in plat 2, 2,196 forms were collected at the sixth picking, while a total of only 2,358 were collected at the other five pickings from this plat. Another important feature is the high percentage of clean forms collected in the bags. This varied from 42.4 to 51.7 in the different plats and averaged 45.7 over the entire series. From this it is seen that almost one-half of the total forms collected in the bag-and-hoop during this series of tests were perfectly clean. In addition to this destruction of clean squares the same loss of terminal buds which was noted in the other tests was observed in this experiment.

It is interesting to compare the form collections of plat 2 with those made on the Hecla test about the same time. This comparison is shown in Table 27.



TABLE 27.—*Comparison of Hecla and Eureka, Madison Parish, La., tests in forms collected in bags.*

| Date.        | Forms collected per acre. |        |
|--------------|---------------------------|--------|
|              | Eureka plat 2.            | Hecla. |
| June 13..... | 123                       | .....  |
| June 16..... | .....                     | 285    |
| June 20..... | 116                       | .....  |
| June 22..... | .....                     | 346    |
| June 27..... | 338                       | .....  |
| June 29..... | .....                     | 414    |
| July 5.....  | 472                       | .....  |
| July 10..... | .....                     | 894    |
| July 11..... | 1,309                     | .....  |
| July 17..... | .....                     | 506    |
| Total.....   | 2,358                     | 2,445  |

In the Hecla test it is seen that during a total of five pickings extending from June 16 to July 17, 2,445 forms per acre were collected, while on plat 2 of the Eureka test the five pickings extending from June 13 to July 11 yielded a total of 2,358 forms per acre. Thus through this period the total forms collected in the two tests were approximately the same. However, a study of the individual pickings shows these totals to have been reached by quite different records. There was a comparatively slight increase on the Hecla test from the first to the fourth picking, and then the fifth picking decreased somewhat. In the Eureka test the first four pickings yielded less than the same number of the Hecla test, but the fifth picking increased several hundred per cent. Two factors undoubtedly influenced this difference of results in the two tests. These were the degree of weevil infestation and the cotton variety. The higher initial infestation of the Hecla test resulted in a greater number of squares being collected on that plat in the early pickings, but the comparative lack of prolificacy and the determinate fruiting of this long-staple variety of cotton was becoming effective by the picking of July 17, and consequently there was an actual reduction in the number of forms collected. On the other hand, the light initial infestation of the Eureka test resulted in low records at the first few pickings, but the rapid increase in this infestation and the enormous abundance of squares caused the later pickings to yield large numbers.

Unfortunately no collections of fallen forms were made in the Eureka plats, so it is impossible to compare the two tests on this point.

TABLE 28.—Row records of weevil collection in bags, *Eureka plantation, Tallulah, La., 1916, test No. 1.*

| Plat.  | Row | Weevils collected in bags. |         |         |         |         |         |        |         |         |            | Row average in blocks. |
|--------|-----|----------------------------|---------|---------|---------|---------|---------|--------|---------|---------|------------|------------------------|
|        |     | June 13                    | June 17 | June 20 | June 23 | June 27 | June 30 | July 5 | July 11 | July 22 | Row total. |                        |
| 2..... | 1   |                            |         |         |         |         |         | 1      | 5       | 19      | 25         | 31.1                   |
|        | 2   |                            |         |         |         |         |         | 1      | 3       | 23      | 30         |                        |
|        | 3   | 1                          |         | 2       |         |         |         | 3      | 5       | 28      | 39         |                        |
|        | 4   | 1                          |         | 1       |         | 1       |         | 4      | 5       | 15      | 27         |                        |
|        | 5   |                            |         |         |         | 3       |         | 3      |         | 3       | 29         |                        |
|        | 6   |                            |         |         |         | 2       |         | 9      | 6       | 20      | 37         |                        |
|        | 7   |                            |         |         |         | 1       |         | 2      | 6       | 36      | 45         | 33.9                   |
|        | 8   |                            |         |         |         | 2       |         | 4      | 3       | 14      | 23         |                        |
|        | 9   |                            |         | 1       |         |         |         | 2      | 3       | 25      | 31         |                        |
|        | 10  | 1                          |         |         |         | 2       |         | 2      | 4       | 29      | 38         |                        |
|        | 11  |                            |         |         |         |         |         | 1      | 4       | 30      | 35         |                        |
|        | 12  | 1                          |         | 2       |         | 2       |         | 9      | 9       | 30      | 53         |                        |
|        | 13  | 1                          |         |         |         | 1       |         | 2      | 7       | 10      | 21         | 22.5                   |
|        | 14  | 1                          |         |         |         | 1       |         | 3      | 5       | 25      | 35         |                        |
|        | 15  |                            |         | 1       |         | 3       |         |        | 7       | 26      | 37         |                        |
|        | 16  |                            |         | 2       |         | 1       |         | 3      | 3       | 12      | 21         |                        |
|        | 17  | 1                          |         |         |         |         |         | 1      | 3       | 9       | 14         |                        |
|        | 18  | 1                          |         |         |         | 1       |         | 5      | 2       | 17      | 26         |                        |
|        | 19  |                            |         |         |         |         |         |        |         | 22      | 22         | 22.5                   |
|        | 20  | 1                          |         |         |         | 1       |         | 2      |         | 27      | 31         |                        |
|        | 21  |                            |         |         |         |         |         | 2      |         | 13      | 15         |                        |
|        | 22  | 1                          |         | 2       |         | 1       |         | 4      | 2       | 17      | 27         |                        |
| 3..... | 1   |                            | 1       |         |         | 1       | 2       |        |         |         | 4          | 3.1                    |
|        | 2   | 1                          | 2       | 1       | 1       |         |         |        |         |         | 5          |                        |
|        | 3   |                            |         |         |         | 2       |         |        |         |         | 2          |                        |
|        | 4   | 1                          | 1       |         |         |         | 1       | 1      |         |         | 3          |                        |
|        | 5   |                            |         |         |         |         | 1       | 1      |         |         | 1          |                        |
|        | 6   | 1                          |         |         | 1       | 1       | 1       | 1      |         |         | 4          | 5.8                    |
|        | 7   |                            | 2       |         |         | 1       | 1       | 1      |         |         | 4          |                        |
|        | 8   | 1                          |         |         |         | 2       | 2       |        |         |         | 4          |                        |
|        | 9   |                            |         |         | 1       | 6       | 2       |        |         |         | 9          |                        |
|        | 10  | 2                          |         |         | 1       | 3       | 2       |        |         |         | 8          |                        |
|        | 11  | 1                          |         | 1       | 2       |         |         |        |         |         | 4          | 2.1                    |
|        | 12  | 2                          | 3       | 1       |         | 2       | 4       |        |         |         | 12         |                        |
|        | 13  |                            |         |         |         | 1       |         |        |         |         | 1          |                        |
|        | 14  |                            |         |         |         | 2       | 2       |        |         |         | 4          |                        |
|        | 15  |                            |         |         | 1       |         |         |        |         |         | 1          |                        |
|        | 16  |                            | 2       | 2       | 4       | 1       | 2       |        |         |         | 11         |                        |
|        | 17  |                            |         |         |         | 1       |         |        |         |         | 1          | 3.6                    |
|        | 18  | 1                          |         |         | 1       |         | 1       |        |         |         | 3          |                        |
|        | 19  | 1                          |         |         |         |         |         |        |         |         | 1          |                        |
|        | 20  | 1                          |         | 1       |         | 1       |         |        |         |         | 3          |                        |
|        | 21  |                            |         |         |         | 1       | 1       |        |         |         | 2          |                        |
|        | 22  | 1                          |         |         |         | 2       |         | 1      |         |         | 3          |                        |
| 4..... | 1   |                            |         | 2       |         | 3       |         | 1      |         |         | 6          | 3.6                    |
|        | 2   |                            |         | 1       |         |         |         | 10     |         |         | 11         |                        |
|        | 3   |                            |         |         |         |         |         | 1      |         |         | 1          |                        |
|        | 4   |                            |         |         |         | 1       |         | 1      |         |         | 2          |                        |
|        | 5   |                            |         |         |         |         |         | 1      |         |         | 1          |                        |
|        | 6   |                            |         |         |         | 1       |         |        |         |         | 1          | 3.6                    |
|        | 7   |                            |         | 2       |         | 1       |         | 1      |         |         | 4          |                        |
|        | 8   |                            |         |         |         | 3       |         | 1      |         |         | 4          |                        |
|        | 9   |                            |         | 2       |         | 2       |         | 5      |         |         | 9          |                        |
|        | 10  | 1                          |         |         |         |         |         | 3      |         |         | 4          |                        |
|        | 11  | 1                          |         |         |         |         |         | 4      |         |         | 5          | 4.5                    |
|        | 12  | 1                          |         |         |         |         |         |        |         |         | 1          |                        |
|        | 13  |                            |         |         |         | 2       |         | 1      |         |         | 3          |                        |
|        | 14  |                            |         | 1       |         | 1       |         |        |         |         | 2          |                        |
|        | 15  |                            |         |         |         | 2       |         |        |         |         | 2          |                        |
|        | 16  |                            |         | 1       |         | 1       |         |        |         |         | 2          |                        |
|        | 17  |                            |         |         |         | 1       |         | 1      |         |         | 2          | 4.5                    |
|        | 18  |                            |         |         |         |         |         |        |         |         |            |                        |
|        | 19  | 1                          |         |         |         | 3       |         | 2      |         |         | 6          |                        |
|        | 20  | 1                          |         |         |         | 1       |         | 3      |         |         | 5          |                        |
|        | 21  | 1                          |         |         |         | 1       |         |        |         |         | 7          |                        |
|        | 22  |                            |         |         |         | 4       |         | 3      |         |         | 7          |                        |

TABLE 29.—Row records of square collection in bags, Eureka plantation, Tallulah, La., 1916, test No. 1.

| Plat.  | Row. | Squares collected in bags. |             |             |             |             |             |            |             |             |      | Row<br>total. | Row<br>average<br>by<br>blocks. |
|--------|------|----------------------------|-------------|-------------|-------------|-------------|-------------|------------|-------------|-------------|------|---------------|---------------------------------|
|        |      | June<br>13.                | June<br>17. | June<br>20. | June<br>23. | June<br>27. | June<br>30. | July<br>5. | July<br>11. | July<br>22. |      |               |                                 |
| 2..... | 1    | 1                          |             | 1           |             | 7           |             | 5          | 12          | 87          | 113  | 145.6         |                                 |
|        | 2    | 2                          |             | 3           |             | 8           |             | 7          | 25          | 97          | 142  |               |                                 |
|        | 3    | 2                          |             | 5           |             | 4           |             | 17         | 15          | 81          | 124  |               |                                 |
|        | 4    | 3                          |             | 2           |             | 7           |             | 10         | 10          | 109         | 141  |               |                                 |
|        | 5    | 9                          |             | 3           |             | 5           |             | 13         | 19          | 134         | 183  |               |                                 |
|        | 6    | 5                          |             | 1           |             | 4           |             | 12         | 16          | 133         | 171  |               |                                 |
|        | 7    | 4                          |             | 4           |             | 5           |             | 12         | 30          | 67          | 122  | 122.9         |                                 |
|        | 8    | 1                          |             | 8           |             | 7           |             | 7          | 13          | 83          | 119  |               |                                 |
|        | 9    | 6                          |             | 13          |             | 10          |             | 16         | 24          | 89          | 158  |               |                                 |
|        | 10   | 5                          |             | 2           |             | 9           |             | 8          | 15          | 138         | 177  |               |                                 |
|        | 11   | 6                          |             | 4           |             | 21          |             | 5          | 5           | 83          | 124  |               |                                 |
|        | 12   | 2                          |             | 4           |             | 13          |             | 13         | 15          | 71          | 118  |               |                                 |
|        | 13   | 3                          |             | 6           |             | 12          |             | 5          | 13          | 44          | 83   | 78.8          |                                 |
|        | 14   | 2                          |             | 1           |             | 16          |             | 11         | 12          | 98          | 140  |               |                                 |
|        | 15   | 8                          |             | 2           |             | 4           |             | 8          | 12          | 74          | 108  |               |                                 |
|        | 16   | 2                          |             | 2           |             | 20          |             | 9          | 9           | 38          | 80   |               |                                 |
|        | 17   | 1                          |             | 3           |             | 5           |             | 5          | 7           | 69          | 90   |               |                                 |
|        | 18   | 3                          |             | 1           |             | 6           |             | 17         | 7           | 50          | 84   |               |                                 |
|        | 19   |                            |             | 2           |             | 6           |             | 5          | 2           | 93          | 108  | 20.1          |                                 |
|        | 20   | 3                          |             | 2           |             |             |             | 5          | 1           | 72          | 83   |               |                                 |
|        | 21   | 3                          |             | 2           |             |             |             | 2          | 3           | 27          | 37   |               |                                 |
|        | 22   | 4                          |             | 2           |             | 10          |             | 9          | 6           | 40          | 71   |               |                                 |
| 3..... | 1    |                            | 5           | 4           | 2           | 3           | 6           |            |             |             | 21   | 29.0          |                                 |
|        | 2    | 6                          | 4           | 10          | 4           | 2           | 3           |            |             |             | 29   |               |                                 |
|        | 3    |                            | 2           | 3           | 1           | 5           | 4           |            |             |             | 15   |               | 22.0                            |
|        | 4    | 1                          | 2           | 1           | 5           | 4           | 5           |            |             |             | 18   |               |                                 |
|        | 5    |                            | 3           |             | 1           | 2           | 4           |            |             |             | 10   |               |                                 |
|        | 6    | 1                          | 5           | 4           |             | 6           | 12          |            |             |             | 28   |               |                                 |
|        | 7    | 2                          | 3           | 8           | 3           | 3           | 4           |            |             |             | 23   | 19.5          |                                 |
|        | 8    | 3                          | 5           | 3           | 4           | 4           | 9           |            |             |             | 28   |               |                                 |
|        | 9    | 3                          | 6           | 7           |             | 8           | 5           |            |             |             | 29   |               |                                 |
|        | 10   | 6                          | 10          | 10          | 4           | 9           | 11          |            |             |             | 50   |               |                                 |
|        | 11   | 7                          | 9           | 5           | 2           | 5           | 8           |            |             |             | 36   |               |                                 |
|        | 12   | 16                         | 5           | 4           |             | 9           | 7           |            |             |             | 41   |               |                                 |
|        | 13   |                            | 1           | 4           | 1           | 5           | 6           |            |             |             | 17   |               | 12.8                            |
|        | 14   | 7                          | 8           |             | 1           | 12          | 2           |            |             |             | 30   |               |                                 |
|        | 15   | 6                          | 4           | 1           | 1           | 4           | 1           |            |             |             | 17   |               |                                 |
|        | 16   |                            | 3           | 2           | 7           | 5           | 2           |            |             |             | 19   |               |                                 |
|        | 17   | 4                          | 1           | 2           |             | 12          | 1           |            |             |             | 20   |               |                                 |
|        | 18   | 5                          | 4           | 1           | 1           | 3           | 5           |            |             |             | 19   |               |                                 |
|        | 19   | 4                          | 3           |             |             | 5           | 5           |            |             |             | 17   | 15.1          |                                 |
|        | 20   | 1                          | 2           | 4           | 2           | 7           | 7           |            |             |             | 23   |               |                                 |
|        | 21   | 2                          |             | 3           | 2           | 8           | 3           |            |             |             | 18   |               |                                 |
|        | 22   |                            | 3           | 8           |             | 5           | 4           |            |             |             | 20   |               |                                 |
| 1      | 2    | 7                          |             |             | 9           |             | 6           |            |             | 24          | 22.0 |               |                                 |
| 2      | 11   | 6                          |             |             | 12          |             | 7           |            |             | 36          |      |               |                                 |
| 3      | 4    | 2                          |             |             | 4           |             | 3           |            |             | 13          |      |               |                                 |
| 4      |      | 4                          |             |             | 6           |             | 6           |            |             | 16          |      |               |                                 |
| 5      | 3    | 1                          |             |             | 2           |             | 4           |            |             | 10          |      |               |                                 |
| 4..... | 6    | 8                          | 3           |             | 13          |             | 9           |            |             |             | 33   | 12.8          |                                 |
|        | 7    | 2                          | 6           |             | 4           |             | 1           |            |             |             | 13   |               |                                 |
|        | 8    | 1                          | 8           |             | 6           |             | 2           |            |             |             | 17   |               |                                 |
|        | 9    |                            |             |             | 4           |             | 7           |            |             |             | 11   |               |                                 |
|        | 10   | 1                          |             | 2           |             | 4           |             | 10         |             |             | 17   |               |                                 |
|        | 11   |                            |             | 2           |             |             |             | 10         |             |             | 12   | 15.1          |                                 |
|        | 12   | 3                          | 4           |             |             | 6           |             | 5          |             |             | 18   |               |                                 |
|        | 13   | 2                          | 5           |             |             | 3           |             | 3          |             |             | 13   |               |                                 |
|        | 14   | 1                          |             |             |             | 7           |             | 1          |             |             | 9    |               |                                 |
|        | 15   | 1                          | 2           |             |             | 1           |             | 8          |             |             | 12   |               |                                 |
|        | 16   | 1                          | 2           |             |             | 3           |             |            |             |             | 6    | 15.1          |                                 |
|        | 17   | 2                          | 4           |             |             | 3           |             | 3          |             |             | 12   |               |                                 |
| 18     | 2    |                            |             |             | 7           |             | 7           |            |             | 16          |      |               |                                 |
| 19     | 2    |                            |             |             | 5           |             | 3           |            |             | 10          |      |               |                                 |
| 20     |      |                            | 7           |             | 10          |             | 5           |            |             | 22          |      |               |                                 |
| 21     | 1    |                            | 1           |             | 5           |             | 5           |            |             | 12          |      |               |                                 |
| 22     | 1    |                            | 7           |             | 10          |             | 1           |            |             | 19          |      |               |                                 |



Row records of the weevil and square collections were made in this test in the same manner as that already described for the Hecla experiment. These are tabulated in Tables 28 and 29. The row totals are averaged by blocks in much the same manner as in the Hecla test. Of course, in this case unpicked cotton adjoined only two of the blocks. These were the outside blocks of plats 2 and 4. From Table 28 it is seen that the outside block of plat 4 averaged slightly higher in weevils collected than the remainder of the plat, but that the outside block of plat 2 averaged less than the middle block of the same plat. From Table 29 it is seen that the square collections presented exactly reversed conditions. From these square collections it would seem that the outside block of plat 2 was more highly infested than the inside, while the rows 1 to 6 of plat 4 yielded a higher average than any of the remainder of the plat. These results are rather contradictory, but at any rate they seem to indicate that if the unpicked cotton had any effect on the picked plats it was comparatively slight and should have been largely eliminated by the buffer system employed.

## WEEVIL INFESTATION.

The infestation of the various plats of this series was followed throughout the season in the same manner as in the Hecla test. The general rule for determining this record was an examination of 100 squares in each end and the middle of each plat. The records secured are shown in Table 30.

TABLE 30.—*Weevil infestation, Eureka plantation, Tallulah, La., 1916, Test No. 1.*

| Date of examination.   | Infestation.     |                  |                  |                                        |
|------------------------|------------------|------------------|------------------|----------------------------------------|
|                        | Plat 2.          | Plat 3.          | Plat 4.          | Plats 1 and 5; average of both checks. |
|                        | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i>                       |
| June 12. ....          | 7.3              | 10.7             | 6.7              | 8.0                                    |
| June 19. ....          | 5.3              | 13.3             | 8.0              | 11.2                                   |
| June 26. ....          | 8.7              | 7.3              | 7.0              | 10.7                                   |
| July 3. ....           | 9.2              | 5.7              | 4.3              | 9.0                                    |
| July 10. ....          | 12.3             | 12.7             | 9.8              | 12.2                                   |
| July 17. ....          | 42.2             | 35.0             | 40.7             | 44.8                                   |
| July 24. ....          | 81.8             | 46.5             | 57.8             | 67.7                                   |
| Aug. 1. ....           | 76.3             | 78.2             | 81.7             | 81.8                                   |
| Aug. 8. ....           | 91.0             | 92.8             | 80.5             | 85.2                                   |
| Aug. 14. ....          | 96.2             | 96.3             | 97.0             | 96.2                                   |
| Weighted average. .... | 50.6             | 46.1             | 46.2             | 49.7                                   |

From these figures it is seen that starting with a practically equal infestation these three treated plats and the two checks varied back and forth somewhat, but never showed any significant regularity in the difference between the various individual plats. In fact, the

range in the seasonal averages of the five plats was only 4.5 per cent and the seasonal average infestation of the three picked plats was 47.6 per cent while that of the two checks was 47.9 per cent.

#### EFFECT ON PLANTS.

The same effect of the picking operation on the plants was observed in this test as in all other bag-and-hoop experiments. It was observed that the shakings were reducing the size of the plants and were causing the typical bushy growth. One thousand plants were measured in each of the plats to determine the average height on July 19, 200 plants being examined at five different points in each plat. The results secured are shown in Table 31.

TABLE 31.—Average height of plants on July 11, Eureka plantation, Tallulah, La., 1916, Test No. 1.

| Plat No. | Treat-<br>ment. | Average<br>height. |
|----------|-----------------|--------------------|
|          |                 | <i>Inches.</i>     |
| 1.....   | Check.....      | 42.7               |
| 2.....   | Shaken.....     | 35.4               |
| 3.....   | do.....         | 37.9               |
| 4.....   | do.....         | 37.5               |
| 5.....   | Check.....      | 40.6               |

From this it is seen that the two checks averaged 40.6 and 42.7 inches in height, while the next highest plat was 3, which averaged 37.9 inches; plat 4 was practically the same height, averaging 37.5 inches, while plat 2 showed the greatest effect of all, averaging 35.4 inches. These differences had been more pronounced earlier in the season, but, following the cessation of shaking, the picked plats had recovered a portion of the lost height by a rapid terminal growth.

The difference in height between plats 1 and 2 is illustrated photographically in figure 2 of plate 2, which shows the dividing line between these two plats.

From these figures showing the effect of the shaking of the plants it is seen that plat 2 was the most seriously injured of the series, while plats 3 and 4 were affected practically the same. This would seem to indicate that it is the duration of the pickings rather than the number which determined the effect on the plants. For example, plats 2 and 3 received the same number of shakings, but the interval was twice as long in plat 2 as in plat 3, so they extended much later into the season and the result was that in the fall plat 2 showed a much greater injury. Plat 3 received two more pickings than plat 4 but the time intervals differed so that the pickings extended over about the same period in the two plats and the resultant effect on the plants was much the same.

## SEED-COTTON PRODUCTION.

The cotton produced on these plats was gathered in three pickings, August 24, September 14, and November 21. The amount secured is shown in Table 32.

TABLE 32.—Seed-cotton production, Eureka plantation, Tallulah, La., 1916, test No. 1.

| Plat.                   | Seed cotton produced per acre. |           |          |         |
|-------------------------|--------------------------------|-----------|----------|---------|
|                         | Aug. 24.                       | Sept. 14. | Nov. 21. | Total.  |
|                         | Pounds.                        | Pounds.   | Pounds.  | Pounds. |
| 2.....                  | 286                            | 478       | 123      | 887     |
| 3.....                  | 172                            | 458       | 175      | 805     |
| 4.....                  | 167                            | 562       | 212      | 941     |
| Average of 1 and 5..... | 297                            | 449       | 119      | 865     |

From Table 32 it is seen that the total range of the plats was from 805 to 941 pounds of seed cotton per acre, or a range of 136 pounds of seed cotton per acre. In this series the checks ranked about midway between the extremes. Plat 4 ranked highest of all, while plat 3 ranked lowest. In view of these rankings and the results of the various studies conducted on these plats during the season it seems impossible to attach any significance to the differences of the yields of the various plats. The total range constituted only 18 per cent of the production of the lowest plat and the plat giving the highest yield logically should have shown less benefit than at least one other plat, if the picking operations had been effective. In fact, one of the check plats yielded 849, while the other yielded 881, showing a difference of 32 pounds between the checks themselves. Consequently, it seems probable that the yield differences were of no significance whatever. At any rate, they fail to show any important beneficial effect from the picking operation. The boll-rot factor which was discussed in connection with the Hecla test was likewise operative in this test, as the checks produced an enormously rank growth, but the reduction in fruiting due to the shaking operation balanced this, so that the yield from the checks was practically equal to that from the picked plats.

#### STUDIES ON THE VALUE OF A MECHANICAL COLLECTOR OF BOLL WEEVILS.

Among the many methods of weevil control advocated and advertised by various individuals throughout the cotton belt are several mechanical collectors of the weevils. These machines vary widely in form and manner of construction, but most of them are similar in the principle involved. Usually they consist of some type of pan arrangement passing along beneath the plants while at the same time the plants are agitated more or less violently, the idea being to shake



the weevils into the pan. A number of different types of these machines have been examined by the writers, and several of the most promising were tested at Tallulah during the season of 1915. The one of these which gave the best results during that season was selected for more intensive studies during 1916. These studies were of two types, (1) plat tests of the machine under field conditions, and (2) comparative efficiency studies to determine the relative weevil-collecting ability of this machine when compared with the bag-and-hoop.

#### PLAT TEST.

The plat test was arranged in somewhat the same manner as the Hecla test which has been described. The experimental principles involved were much the same, and the same methods of arranging the plats and buffers were followed. A very uniform strip of light sandy soil was selected, and the plant growth over the entire experimental area was rather unusually uniform. The light soil was selected in order to secure plants of comparatively small size, since the machine had shown a tendency to break larger plants rather severely. Two plats were arranged, each 20 rows wide and 740 feet in length. One of these was picked with the machine, while the other was left unpicked as a check.

#### PICKINGS.

The first picking was made on these plats on July 1. Originally it was intended to start this picking somewhat earlier, but delay in securing the machine postponed it until this date. However, as has been mentioned, cotton of small size was secured, and the light and late weevil emergence into this cut was such that only a slight infestation was present on the 1st of July. Consequently, the conditions more or less approximated those which would usually prevail about two weeks earlier in a more severely infested cut of richer soil.

Table 33 shows the detailed results of the various pickings conducted.

TABLE 33.—*Pickings with mechanical collector, Tallulah, La., 1916.*

| Date.        | Weevils collected. | Bolls collected. |           | Squares collected. |           | Time required. |          |
|--------------|--------------------|------------------|-----------|--------------------|-----------|----------------|----------|
|              |                    | Clean.           | Infested. | Clean.             | Infested. | Hour.          | Minutes. |
| July 1.....  | 40                 |                  |           | 103                | 112       | 1              |          |
| July 11..... | 156                | 15               | 115       | 364                | 665       |                |          |
| July 24..... | 450                |                  | 362       | 21                 | 1,700     | 1              |          |
| July 31..... | 1,117              |                  | 296       |                    | 2,281     | 1              | 10       |
| Aug. 7.....  | 1,299              |                  | 397       |                    | 2,235     |                | 45       |
| Aug. 15..... | 2,445              |                  | 301       |                    | 1,363     |                | 45       |
| Aug. 21..... | 2,037              |                  | 457       |                    | 2,037     |                | 45       |
| Aug. 27..... | 1,064              |                  | 231       |                    | 1,079     |                | 45       |
| Tal.....     | 8,608              | 22               | 2,274     | 488                | 11,475    |                |          |

From this it is seen that a total of eight pickings was distributed over the period from July 1 to August 27. The weevils per picking ranged from 40 to 2,445, and a total of 8,608 were collected during the experimental period. As the plat consisted of 1.53 acres, the weevils collected per acre thus ranged from 26 to 1,600 at the different pickings, with a total per acre of 5,626. During this same time 2,274 infested bolls and 11,475 infested squares were collected in the pans with the weevils. During the first three pickings a record was kept of the number of uninjured forms knocked off by the machine, and this was found to total 22 bolls and 488 squares. After that time the forms collected were so highly infested that they were considered as all injured. The time required for covering the plat ranged from 45 minutes to 1 hour and 10 minutes. This would make the average time in the neighborhood of 40 minutes to the acre. However, this did not include the time spent in emptying the pans. Studies on the operation of this machine over larger areas have shown that it may be expected to cover an average of 10 to 12 acres per day when operated on a plantation basis.

#### BROKEN PLANTS.

The greatest difficulty which was found in the operation of this machine was the breakage of plants. It was found that if the machine was adjusted so that the plants were not broken it failed to catch an appreciable number of weevils, while if it was adjusted so that it collected a considerable number of weevils the plant breakage was very high. Consequently, in adjusting the machine, an attempt was made to strike a happy medium between these two extremes.

Following each picking, the plat was gone over and the number of broken plants counted. It was found that the number per picking ranged from 37 plants to 704 plants. The number decreased rapidly as the season progressed, owing to the fact that nearly all of the larger plants had already been broken down. During the course of the eight pickings a total of 1,827 plants were broken in the plat.

#### FALLEN FORM COLLECTIONS.

In order to determine whether or not the forms collected in the picking machine decreased the number reaching the ground to any appreciable extent two collections of fallen forms were made. For this purpose an area 3 rows wide and 20 feet long was selected at each end and the middle of each plat. This made a total of about 750 square feet for each plat. Care was taken to locate these points where the stand was as nearly perfect as possible and where the plant growth represented about the average of that portion of the plat. The results of these collections are shown in Table 34.

TABLE 34.—*Fallen form collections in machine-picked test, Tallulah, La., 1916.*

| Date.        | Picked plat. |        |              | Check plat. |        |              |
|--------------|--------------|--------|--------------|-------------|--------|--------------|
|              | Squares.     | Bolls. | Total forms. | Squares.    | Bolls. | Total forms. |
| July 27..... | 1,385        | 516    | 1,901        | 1,371       | 805    | 2,176        |
| Aug. 5.....  | 1,436        | 372    | 1,808        | 2,581       | 984    | 3,565        |
| Total.....   | 2,821        | 888    | 3,709        | 3,952       | 1,789  | 5,741        |

From this table it is seen that on both occasions considerably more forms were gathered from the ground in the check plat than in the picked plat. In the two pickings a total of 3,709 fallen forms were gathered from the picked plat and 5,741 from the check, thus giving a reduction of 2,032 in favor of the picked plat.

## INFESTATION.

The degree of weevil infestation in the two plats was followed through the season in the usual manner in order to determine the effect of the picking operations. Table 35 gives the results of these observations.

TABLE 35.—*Square infestation, Tallulah, La., 1916.*

| Date.        | Picked plat.     | Check plat.      |
|--------------|------------------|------------------|
|              | <i>Per cent.</i> | <i>Per cent.</i> |
| July 1.....  | 14.3             | 14.3             |
| July 7.....  | 21.4             | 17.2             |
| July 13..... | 47.7             | 38.0             |
| July 21..... | 60.3             | 57.2             |
| July 27..... | 66.8             | 75.0             |
| Aug. 2.....  | 85.3             | 85.3             |
| Aug. 8.....  | 88.8             | 90.3             |

From this it is seen that at the beginning of the experiment the two plats averaged exactly the same infestation. At the next examination, however, the picked plat increased slightly above the check plat and retained this position until July 27. The seasonal average of the check plat was 53.9 per cent, while that of the picked plat was 54.9 per cent. Thus these records fail to show any decrease in the infestation due to the weevil collections. In fact, the averages are remarkably nearly equal. Studies on the seasonal average infestation of the various points of observation show this infestation to have been evenly distributed in the various plats.

## EFFECT ON PLANTS.

The plant breakage due to the operation of the machine has been mentioned. By the latter part of the season it was quite obvious that this was going to have a very detrimental effect on the picked plat. The picked cotton looked as if it had been topped, and it was



easy to distinguish the last picked row at a glance, as this row was a foot or more shorter in height than the adjoining unpicked row.

## PRODUCTION.

The seed cotton produced in these two plats was picked on August 24 and October 26. The amounts secured are shown in Table 36.

TABLE 36.—Seed-cotton production, mechanical picker test, Tallulah, La., 1916.

| Date picked. | Seed cotton per acre. |                       |
|--------------|-----------------------|-----------------------|
|              | Check plat.           | Picked plat.          |
| Aug. 24..... | <i>Pounds.</i><br>216 | <i>Pounds.</i><br>182 |
| Oct. 26..... | 190                   | 109                   |
| Total.....   | 406                   | 291                   |

From this it is seen that the check yielded considerably more than the picked plat each time and in the total of the two pickings there was a loss of 115 pounds of seed cotton per acre in the picked plat. This amounts to a loss of 28 per cent below check and shows quite well the injurious effect of the picking operations with this machine.

## COMPARATIVE EFFICIENCY STUDIES.

As a further check on the efficiency of the machine it was tested in comparison with the bag-and-hoop simply on the basis of efficiency in operation.

The first test was conducted on July 13. A uniform strip of cotton 14 rows wide and 645 feet in length was selected. The method followed was to pick two of these rows with the mechanical picker, then two with the bag-and-hoop, then two with the mechanical picker and so on until eight rows had been picked with the mechanical picker and six with the bag-and-hoop. Records were kept of the number of weevils and forms collected by each of these methods, and the time required was likewise noted. This test was repeated in an identical manner on the same cotton August 3. The results of these two tests are shown in Table 37.

TABLE 37.—Comparative efficiency tests, mechanical pickers, Tallulah, La., 1916.

| Date.        | Mechanical picker (per row).    |                 |        |                 |        |                       | Bag-and-hoop (per row).         |                 |        |                 |        |                       |
|--------------|---------------------------------|-----------------|--------|-----------------|--------|-----------------------|---------------------------------|-----------------|--------|-----------------|--------|-----------------------|
|              | Wee-<br>vils<br>col-<br>lected. | Squares.        |        | Bolls.          |        | Time<br>re-<br>quired | Wee-<br>vils<br>col-<br>lected. | Squares.        |        | Bolls.          |        | Time<br>re-<br>quired |
|              |                                 | Punc-<br>tured. | Clean. | Punc-<br>tured. | Clean. |                       |                                 | Punc-<br>tured. | Clean. | Punc-<br>tured. | Clean. |                       |
| July 13..... | 2.6                             | 9.6             | 5.9    | 1.0             | 0.25   | <i>Min.</i><br>2      | 9.9                             | 37.0            | 15.3   | 16.0            | 3.8    | <i>Min.</i><br>20     |
| Aug. 3.....  | 48.4                            | 163.1           | .....  | 14.7            | .....  | 3                     | 77.5                            | 280.6           | .....  | 25.0            | .....  | 20                    |

From Table 37 it is seen that at the first test the mechanical picker averaged 2.6 weevils per row while the bag-and-hoop averaged 9.9. At the second test the averages were 48.4 and 77.5, respectively. This shows definitely that the mechanical picker does not even approach the bag-and-hoop in the number of weevils collected from any given area and, since the bag-and-hoop certainly does not collect all present, the mechanical picker must leave a very high percentage. The observations on the infested forms collected likewise show the bag-and-hoop to be very much superior to the mechanical picker. It is only in the time required that the mechanical picker shows an advantage over the bag-and-hoop. These figures show the bag-and-hoop to require about 20 minutes per row, while the mechanical picker required only from two to three minutes per row.

One interesting observation was made on the comparative efficiency of different individuals when using the bag-and-hoop. While conducting the test on July 13, it was noted that one of the negroes operating the bag-and-hoop was very fast, while the other one was very slow. Consequently, separate records were kept for these two women. It was found that the faster woman took just one-half the time to the row that the slower one did, and the faster woman averaged 14 weevils per row while the slower one averaged 4. This is an excellent example of the variation in the efficiency of the individual pickers.

#### GENERAL CONSIDERATIONS AND SUMMARY.

The studies described in the preceding pages, together with those of the season of 1915,<sup>1</sup> seem to warrant some conclusions on the subjects dealt with and a general consideration of their relation to the planter.

Two points stand out preeminently in the results of the studies of 1916. These are (1) the complete failure of the picking operations to exert any appreciable beneficial effect on the weevil infestation, and (2) the injurious effect of the use of the bag-and-hoop upon the plants themselves. All points considered in connection with these studies, such as the degree of weevil infestation, plant fruitage, and actual yield, have shown consistently that the bag-and-hoop treatments were not reducing the weevil infestation within the treated plats to any extent. The control exerted by the collections of the weevils seems to have been completely overcome by the number of weevils escaping capture. In this connection it is interesting to compare the results of 1915 with those of 1916. It will be recalled that studies on the collection of fallen forms conducted in the face of the light weevil infestation prevailing during 1915 resulted in a definite

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<sup>1</sup> U. S. Dept. Agr. Bull. 382.

weevil-control reaction, though this control was by no means complete. In 1916, however, with a rapid multiplication of weevils and a heavy infestation, no evidence of control was secured from the weevil collection. The question of the relation of the degree of infestation to the effect secured from practicing these control measures has been raised frequently, and apparently it has a very definite bearing on the difference in the results secured during the two years. It might appear that if a certain amount of benefit is to be derived from the control measures during a year of light infestation, this benefit will be increased proportionately in a year of heavy infestation. The results secured do not support this idea, however, and it seems to the writers that a year of light infestation, such as prevailed during 1915, presents the optimum conditions for securing the maximum degree of control from the picking operation. It must be conceded that the most thorough picking operation will not secure all the weevils present; say, for the sake of discussion, that 75 per cent are secured. If 100 weevils per acre are present in the field at the time of the picking (as would be the case during a light infestation), 25 would be left, and this number would be below that required to produce serious injury to the crop. On the other hand, assuming that there were 1,000 weevils per acre in the field and 75 per cent of these were collected, 250 would still remain, which would be sufficient to produce great injury to the crop, if not the maximum injury. It must be recognized that the degree of weevil injury in the field is not always directly proportionate to the number of weevils present; that is, the amount of injury per weevil decreases considerably with the increase of the number of weevils per acre, owing to the lessened chances of each individual for injury and what might be called the "duplication of effort" in the repeated puncturing of the same form. With the average degree of infestation reached in the Delta during midsummer, there is a great excess of weevils for producing the maximum injury to the crop, and a considerable number of these can be removed from the field without increasing the crop secured to any appreciable extent.

In addition to this consideration, the actual effect of this collection of over-wintered weevils in relation to their propagation is of interest. Under normal conditions, the percentage of squares punctured during the period when the weevil pickings are practiced is comparatively low. The normal shedding of forms in upland cotton is so high that the squares punctured by these hibernated individuals simply serve to take the place of a portion of those which would be shed normally. Consequently, these over-wintered weevils do not injure the cotton crop directly; their only effect on the crop itself in such a case lies in the progeny they produce and the activity of these progeny. Therefore, the only beneficial effect secured from collecting these hibernated



weevils would be the reduction of their progeny. In practice it is found that two factors serve to prevent the complete elimination of these progeny. These are the eggs deposited by the weevils before capture and the percentage of hibernated individuals actually escaping capture. As has been stated, if undisturbed, the weevils in the Delta usually will produce more than sufficient progeny to cause a maximum crop injury by midsummer. In view of the results of the control experiments under heavy infestation conditions, it seems that enough weevils were missed and sufficient eggs were deposited before collection by those actually captured to develop sufficient progeny for a maximum infestation of the crop.

In view of these considerations, it seems to the writers that in a year of light infestation a slight degree of benefit may be secured from the picking operations, but that in a year of average or heavy infestation this benefit is completely lost. This conclusion is borne out by the experiences of various planters which have come under the observation of the writers, and is especially discouraging in view of the fact that in a year of heavy infestation the control measure is most needed.

Another point of primary importance in connection with the plantation use of these control measures is the labor problem. This requires a consideration of the labor supply available on the average Delta plantation, the labor requirements of the ordinary plantation operations, and the labor requirements of the weevil-picking operation. In the first place, it is advisable to consider the organization of the labor by which these picking operations are to be conducted. These measures are practiced only on a tenant basis, where a "family" takes care of a certain quantity of land. This land usually is divided between cotton and corn, the greater portion being in cotton. In addition to the labor involved in caring for this land it is necessary for the plantation to levy upon the male members of these families for a certain amount of wage labor to be used in the care of the oat and hay crops, which are handled only on a wage basis.

#### RELATION BETWEEN LABOR SUPPLY AND MALARIA.

The Bureau of Entomology is conducting an investigation on the Hecla plantation, the estate where one of the writers' tests was conducted, on malaria mosquitoes and their control. In determining the exact relation of malaria to crop production, Dr. D. L. Van Dine made a detailed analysis of the available and required labor on this plantation. In his published account<sup>1</sup> of this work, Dr. Van Dine gives a chart showing the duration of each of the operations involved

<sup>1</sup> Van Dine, D. L., "The relation of malaria to crop production." *In* The Scientific Monthly, November 1916, p. 431-439.

Van Dine, D. L., "The losses to rural industries through mosquitoes that convey malaria." *In* Southern Medical Journal, Vol. VIII, No. 3, p. 184-194. March, 1915.

in the production of cotton, corn, and oats and a table showing the labor requirements of each operation for each crop. From these the writers have prepared figure 1. This diagram shows not only the period of each operation for each crop but also, by the block system, the labor requirements of each crop.

In this chart the writers have added a block showing the labor requirements for weevil picking in the same manner. This was figured on a basis of four pickings with the bag-and-hoop, extending

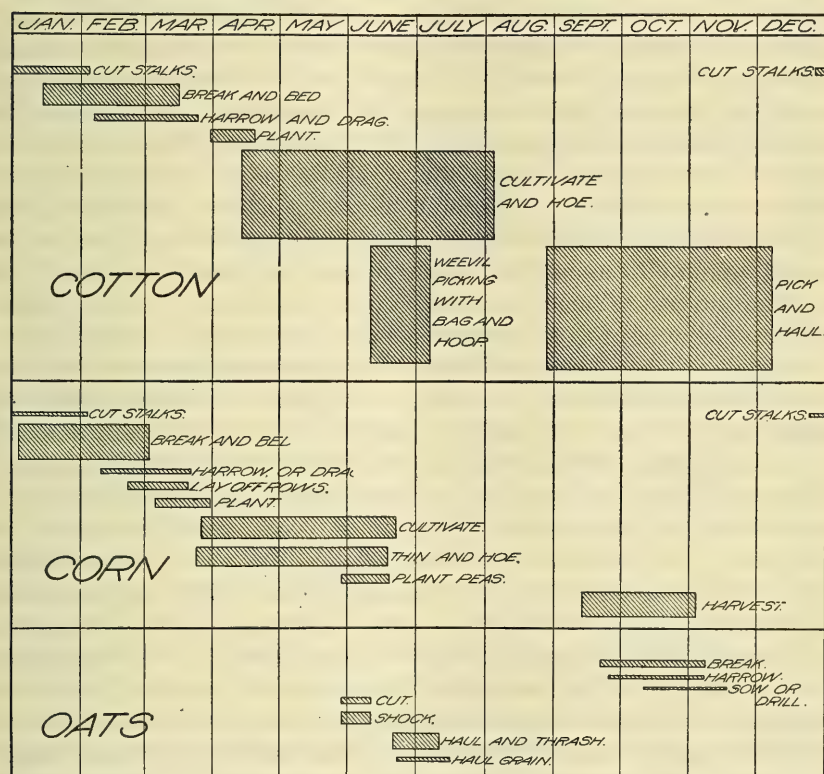


FIG. 1.—Seasonal distribution of field labor in northern Louisiana. Based on 823 acres of cotton, 657 acres of corn, and 200 acres of oats. (Original.)

over the period from June 10 to July 8, making the time interval between pickings about one week. The total acreage in cotton was 823 acres. Of course, all of this would not be picked over under normal conditions; particularly since the work would be more or less concentrated on the more heavily infested portions. Consequently, it was assumed for the sake of conservatism that only two-thirds of this acreage would be treated, or 548 acres. Extensive observations on the time required for the operation of the bag-and-hoop have shown that about the best which can be expected is an

average of one and one-fourth acres per hand per day. However, these calculations were made on a basis of one and one-half acres per hand per day. At this rate, each picking of the 548 acres would require 365 labor days, making the four pickings require a total of 1,460 labor days.

In his paper Dr. Van Dine shows that the labor requirements of the ordinary plantation operations (excluding boll-weevil control) on this plantation during the month of June were 1,814 days. He also showed that the available labor days during this same month were 1,719. In other words, there was an actual shortage of 95 labor days during this month. Considering that three of the weevil pickings would fall during the month of June, a total of 1,095 June labor days would be required for conducting this operation, and as there is already a deficit of 95 labor days, this would make a total of 1,190 days of labor shortage during the month of June. Consequently, if the weevil control is practiced it must be at the expense of the neglect of some of the ordinary plantation operations. In fact, it would amount to about two-thirds neglect of these operations. In figuring the cost of malaria to the plantation Dr. Van Dine has shown that each day of crop neglect produced a loss of \$5.11. Since every labor day put in at weevil picking would mean a labor-day neglect of the other operations, it is seen that, while no direct outlay for wages might be involved, the 1,460 days required would really amount to an expenditure of \$7,300 at the rate of \$5 per day loss for neglect. While this may be reduced by reducing the number of pickings, that would still not relieve the labor crisis which is shown in Diagram I, as the amount of labor required for each picking would still be the same unless they were conducted at longer time intervals. It is interesting to note that this same Hecla plantation attempted a thorough and systematic control of the weevils by the bag-and-hoop collection of the weevils in 1914, and this resulted in such a complete derangement of the ordinary operations without any benefit with regard to weevil infestation being shown, that the attempt has never been repeated. Although these figures of available labor are based on this plantation only, this plantation certainly is as well supplied with labor and as well organized as any in the district in which it is located.

The writers have had the opportunity of examining the original data upon which Dr. Van Dine's figures are based. Table 38 is a summary of the figures obtained on Hecla plantation in 1914 on the age, sex, and numbers of the 74 tenant families, giving the total number available for field work, the theoretical equivalent in man days, and the actual man days available for field work.



TABLE 38.—*Available labor by sex and age groups on Hecla plantation during 1914.*

| Age groups.....                            | Male.  |         |          |        | Female. |         |          |        | Total. |
|--------------------------------------------|--------|---------|----------|--------|---------|---------|----------|--------|--------|
|                                            | 0 to 7 | 8 to 12 | 13 to 18 | 19 up. | 0 to 7  | 8 to 12 | 13 to 18 | 19 up. |        |
| Number individuals present.                | 19.0   | 14.0    | 29.0     | 82.0   | 24.0    | 18.0    | 26.0     | 87.0   | 299.00 |
| Reduced to theoretical man-days labor..... |        | 4.5     | 14.5     | 82.0   | .....   | 2.25    | 6.5      | 43.5   | 153.25 |
| Actual man-days labor.....                 |        | 2.38    | 7.68     | 43.4   | .....   | 1.19    | 3.44     | 23.03  | 81.12  |

It will be observed from Table 38 that after determining the actual individuals of the various sex and age groups present on Hecla plantation this was reduced to a basis of the theoretical number of man days of labor in each of these groups. However, it is quite obvious that this theoretical figure does not represent the available labor actually present. Certain factors operate on all plantations to reduce this theoretical labor. Again referring to the study made by this bureau on the relation of malaria to crop production, the following estimate has been made of the reduction in the available labor supply:

In 1914, 138 persons in the tenant families out of a total of 299 suffered from malaria. Dr. L. O. Howard is the authority for the statement that the efficiency of a person suffering from malaria is reduced 25 per cent. Not taking account of the cases in children under 8 years of age and reducing the ages of those above 8 years to an equivalent of adult time, an equivalent of the time of 18.5 adult men was lost during the season of 1914 through inefficiency due to malaria.

It is a fact that the negro is incapable of maximum continuous effort during an entire day when at work, and aside from illness or other demands on his time will not under the tenant system work in the field every day when field work is possible. It is necessary to figure not a man day but a negro-man day, and this falls far short of what may be expected when continuous effort is made during the entire day and full advantage taken of working in the field on all days when field work is possible. Thirty days can not be counted on in every month for field work, since account must be taken of Sundays, holidays, and the weather conditions. The error would be as great to figure as available all labor not necessarily detained at home. Account must be taken of the class of labor upon which dependence is placed. It is considered that 25 per cent must be deducted from the total adult time available for this reason. Of the labor available on Hecla in 1914, this would be equivalent to the time of 38.31 adults.

## OTHER CONSIDERATIONS CONNECTED WITH LABOR.

It is estimated that a further reduction of 10 per cent in the available labor must be made, to allow for the "pensioners" on the plantation, for those suffering from diseases other than malaria, for the care of infants and the cooking on the part of the women, and for absences from the field on account of funerals and other interruptions. This is equivalent to the time of 15.32 adults. The actual total adult time available, then, is only 81.12 instead of 153.25 adults. In Table 38 this available time has been reduced to adult time in the various groups arranged by age and sex.

Based on averages of 50 plantations in northern Louisiana, the Office of Farm Management of this department estimates that there are 19.1 days in June when field work is possible on a plantation. Taking this as a basis the various age groups shown in Table 38 have been reduced to available labor for the entire month of June. This is shown in Table 39.

TABLE 39.—*Total man days available of different types of labor on Hecla plantation during June, 1914.*

| Age groups.....                   | Male.   |          |         | Female. |          |        | Total.   |
|-----------------------------------|---------|----------|---------|---------|----------|--------|----------|
|                                   | 8 to 12 | 13 to 18 | 19 up.  | 8 to 12 | 13 to 18 | 19 up. |          |
| Theoretical labor days available. | 85.95   | 276.95   | 1,566.2 | 42.97   | 124.15   | 830.85 | 2,927.07 |
| Actual labor days available.....  | 45.45   | 146.68   | 828.94  | 22.72   | 65.70    | 439.87 | 1,549.36 |

Taking the figures shown in Table 39, it is possible to determine just what classes of labor could be used in this weevil-picking work on the basis of three pickings requiring 1,095 labor days during June. Taking the actual labor days available in the different classes, it is seen that there are 22.72 in the group of females from 8 to 12 years of age, 65.7 females from 13 to 18, and 439.87 females of 19 or older. Consequently, the total man days of labor available of the female sex on Hecla plantation during June is 528.29. It is obvious that it would be necessary to take some male labor as well for the picking operation. There are 45.45 labor days of boys from 8 to 12 years of age. Adding this to the female labor makes only 573.74 labor days. There are 146.68 labor days of males from 13 to 18. Adding this to the preceding total gives 720.42 labor days, which is still 374 days short of the number required for the weevil-picking work. In other words, if all the female labor and all of the male labor under 19 years of age were devoted to weevil picking there would still be a shortage of 374 labor days for the picking operation. As the only labor left available is the males of 19 years or older, some of these must be utilized on the picking work. There are approximately 829 labor

days of this group available. Consequently, if we subtract the labor required for the picking operation from that available during June there are only 455 labor days remaining. However, it was found in the malaria investigations that 199 labor days were lost directly because of malaria during June, and subtracting this number from the 455, there are only 256 labor days left for conducting all ordinary plantation operations during the month of June, and it has been shown that these ordinary operations require a total of 1,814 labor days.

Going back to Table 39, it is of interest to calculate just what proportion of the theoretical labor would be required. If the three groups of female labor and the males from 8 to 12 are totaled, it is found that 1,093.92 days result. In other words, even on the basis of the theoretical labor, which is far from the actual labor available, it would require all of the females and all of the males up to 13 years of age to conduct the picking operations.

These observations on labor requirements and available labor seem to show definitely the impracticability of the systematic use of the bag-and-hoop on the plantation. Since comparative efficiency observations have shown that the bag-and-hoop requires only one-fourth as long as the hand picking of weevils and collects twice as many to the acre, the outlook for hand picking is very discouraging to say the least. As the labor available is not sufficient to conduct the bag-and-hoop collections, it certainly is not sufficient for the hand pickings, which would require four times as much labor. In addition, if the proportion of weevils collected with the bag-and-hoop is not high enough to benefit materially an average or heavy infestation, there seems to be little chance of securing a benefit from hand picking one-half this number of weevils. Still another method of control is the hand collection of fallen squares. Observations on the labor requirements of this have shown that the best which can be expected is one acre per day per hand. Thus this operation would require one-third more labor than the operation of the bag-and-hoop and is eliminated in the same manner.

The type of labor available for this weevil picking and the type required are also of interest. In view of the general labor shortage prevailing in the Delta, it is necessary for the women to assume the responsibility of all operations possible. This naturally results in their use as hoe hands in restraining the grass growth in both cotton and corn, particularly cotton. In case of a rain delaying operations and causing an excess of grass growth, it falls to their lot to save the cotton crop by hoeing, while the men are attempting to catch up with the strictly masculine operations. This condition is met at some time practically every season in the Delta and shows the importance



of the women in the labor complex of ordinary operations. Under such conditions (and these are normal conditions in the Delta) the only labor left available for weevil and square picking operations without taking hands from some other operations is that of the children who are too small to hoe.

In this connection it is necessary to consider the type of labor required for the control operation. It would seem that the children and such women as might happen to be available should be able to reduce the weevil infestation somewhat by picking, but this is not the case. As a general rule negro children working alone will accomplish nothing. Their only incentive for effective work lies in the continued presence of older people who will force them to work properly and continuously. This would of course involve the presence of at least a few women with each group of children, and when the family is the unit the mother would be forced to neglect the hoeing and work with the children. Even this would be practicable under some conditions if it were not for the attitude of the women. It is generally recognized that negro women are very unsatisfactory workers at many plantation operations without the presence of men to keep them at work. This is particularly true of the weevil-picking operation, as this work is very distasteful to them and they wish to slight it. Of course this is due to the fact that the incentive for performing arduous and distasteful labor is not as great with the women as with the men because, generally speaking, the women are not as much concerned as the men in securing a successful crop. As a result it is generally found that to secure a picking which in any way approaches thoroughness it is necessary to have a certain number of men with each force of laborers. At any rate, regardless of the necessity of the presence of men, a small amount of child labor is in reality the only surplus labor available, and this is certainly far from sufficient to produce any effect upon the weevil infestation. Any addition to this labor only depletes the ranks of those employed in the ordinary plantation operations, and must result in some neglect.

The discovery of the injurious effect of the use of the bag-and-hoop on the plant is of great importance. Owing to the seriousness of the labor problem concerned in these operations, the first studies of the use of the bag-and-hoop looked very encouraging, as it was certainly a great advance over hand picking in both speed and efficiency of operation. However, the studies of the past season have shown definitely that the use of this semimechanical picker can not be recommended.

The studies on the infested forms collected by the bag-and-hoop are considerably reduced in practical importance by the discovery of the injurious effect of this collector on the plants. However, the general tendency of these studies is to emphasize this injurious effect,

as from 25 to 50 per cent of the forms which were collected in the bags proved to be uninfested. Of course, a certain percentage of these were uninjured forms which would shed normally, but a considerable number undoubtedly were good forms which were broken off by the shaking process.

The comparison of the two varieties of cotton was not sufficiently complete to allow any general conclusions, but the most important point seems to be that the bag-and-hoop collects a higher proportion of the infested squares on the long-staple variety than on the short.

The failure of the mechanical picker to give satisfactory results is very discouraging, as such a picker seems the only solution of the labor problem involved in the collection of weevils and squares. As has been mentioned, the picker tested was the most promising which had come under the observation of the writers, but proved to miss a sufficient number of weevils practically to prevent any reduction in the infestation. In addition, this picker was so injurious to the plants that it actually reduced the crop considerably.

The information secured on the interplat movement of the weevils in the various field experiments is of considerable importance in the interpretation of the results of such tests. It is seen that in each case there was a more or less increased infestation in the picked rows immediately adjoining the unpicked cotton. However, this was usually slight and extended only a short distance, so it was certainly not sufficient to prevent the control measures from producing a beneficial effect in the treated plats, if they would do so under field conditions. This conclusion is borne out by the fact that identical tests where the control measure tested proved effective have shown a quite definite control reaction within these comparatively small plats. It is probable that the small size of the plats would somewhat reduce the extent of the gain in production from any beneficial treatment owing to the immigration of the weevils from unpicked cotton late in the season, but it seems fair to assume that when applying these results to field conditions this factor would be at the very least counterbalanced by the greater thoroughness of the picking operations in these plat tests. It should be remembered that a limited number of pickers were used in all of these plat tests and that they were under the constant supervision of one or more of the entomologists. As a result, the operations were conducted far more thoroughly than would be possible under field conditions.

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THE ability to candle accurately is becoming of increasing importance to all who are engaged in the production, transportation, and sale of eggs. Buyers are gradually adopting the practice of purchasing eggs on a graded basis as an effective means of reducing the large losses from bad eggs. For the successful operation of such a system a knowledge of candling is indispensable. Furthermore, only by candling can a shipper make certain that his eggs comply with Federal, State, and municipal regulations.

Eggs are graded for market according to their freshness, cleanliness, size, color, and soundness of shell. Freshness, an egg's most important quality, and soundness of shell can be judged best by candling in a dark room. All that is needed is a bright light surrounded by a shield with a small opening before which the egg is held. A kerosene lamp and a piece of stovepipe will suffice for the small candler, but for those who handle large numbers of eggs more elaborate apparatus may prove necessary. Two different kinds of egg-candling devices are illustrated in this bulletin.

The candler must be thoroughly familiar with the structure of the egg. He must know how to hold an egg when candling it. Most important of all, he needs to become acquainted with the principal distinguishing characteristics of each kind of egg found in commerce before he will be able to determine accurately whether a given egg should be graded as marketable or unmarketable. The purpose of this bulletin is to furnish the information required. The candler himself will have to supply the experience.

Sometimes an egg is so near the border line that it is hard to know whether to class it as good or bad. When there is any doubt as to its fitness for food purposes, the candler should reject the egg as inedible; that is, he should give the consumer the benefit of the doubt.



# UNITED STATES DEPARTMENT OF AGRICULTURE



## BULLETIN No. 565

Contribution from the Bureau of Chemistry  
CARL L. ALSBERG, Chief



Washington D. C.



May 11, 1918

### HOW TO CANDLE EGGS.

By M. E. PENNINGTON, *Chief, Food Research Laboratory*, M. K. JENKINS,  
*Assistant Bacteriologist*, and H. M. P. BETTS, *Artist*.

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| The structure of the egg ----- | 3     | the candle and out of the shell---    | 12    |

#### INTRODUCTION.

Ability to candle eggs is becoming more and more important to farmers, merchants, and shippers in the country districts.

Laws in many States impose a penalty for selling bad eggs and the Federal Food and Drugs Act prohibits the interstate shipment of cases containing substantial percentages of bad eggs, which are held to be adulterated food. Only by candling can a shipper make certain that his eggs comply with Federal, State, and other regulations.

Aside from its value in enabling one to comply with legal requirements, ability to judge the condition of eggs in the shell has a distinct monetary application and in many sections is simply a matter of economic self-protection for the farmer and the country dealer. The custom of buying eggs on a grading basis is spreading rapidly, and the collectors in the great market centers are becoming much stricter in rejecting inedible eggs, just as consumers are becoming more critical and are refusing to pay for doubtful eggs delivered to them by the retailer. The producer or country shipper who ships uncandled eggs runs the risk, therefore, of losing freight charges and packing costs on all inedible eggs, and where such eggs are included may get



a lower grading and a reduced price for the good eggs he has shipped. The shipper who does not candle his eggs has no check on the candling reports of the consignee and must accept loss off, lowered grading, or other price penalties.

Knowledge of candling and sorting sufficient to sort eggs by the various commercial grades used in the central markets is, of course, a valuable asset to the country collector and shipper. Ability to use the candle at least with accuracy enough to exclude inedible eggs is becoming an accomplishment essential to all who wish to escape legal difficulties and to market their produce on anything like a profitable basis. The detailed descriptions, diagrams, and colored plates in this bulletin, it is believed, will enable producers, dealers, and housewives to distinguish with sufficient accuracy between edible and inedible eggs. The authors caution those who are first attempting to candle for market to give the benefit of the doubt to the consumer and to retain for home use any eggs which appear at all questionable before the candle.

### GRADING OF EGGS.

Eggs are graded for market according to freshness, cleanliness, size, color, and soundness of shell. Sorting according to size, color, and cleanliness requires only a visual inspection of the egg while it is being held in the hand. At the same time eggs clearly showing damaged shells may be separated. When the crack is so small that it is not easily seen with the naked eye, it can be detected by candling or by clicking two or more eggs together. A cracked egg tapped lightly against a whole egg gives out a deadened sound, quite different from the clear ring from eggs with unbroken shells. It is comparatively easy to grade eggs according to appearance and soundness of shell, but it requires knowledge and experience to be able to judge the quality of the contents by candling.

### THE EGG CANDLE.

The only equipment necessary for candling eggs is a device which consists of a bright light surrounded by a shield having a small opening of sufficient size to receive the egg. Farmers who have few eggs to market can make a candle by using a kerosene lamp as a source of light and a piece of stovepipe about 8 inches long as a shield. The hole should be  $1\frac{1}{4}$  inches in diameter and should be cut in the pipe just opposite the flame in the lamp. Notches, or small openings, should be cut in the bottom of the pipe opposite the hole, to provide air for the lamp. A candle similar to that just described is shown in figure 1.

Handlers of large numbers of eggs, such as hucksters, grocers, and egg shippers, should have a candle made especially for the work. A good candle which can be made by any tinner is illustrated in figure 2. Working drawings are given in figure 3. A strong white electric light should be used in this candle.

### THE STRUCTURE OF THE EGG.

Before attempting to candle, the beginner should break a good egg into a saucer and become familiar with its different parts and their arrangement. By comparing the egg in the saucer with figure 4, in which the structure of a typical egg is shown, and following the description given below, the various parts of the egg can be identified easily.

The yolk is contained in a membrane of delicate construction. It varies in color from light yellow to orange, but occasionally is olive green. On the surface of the yolk is a small light-colored circular area called the germinal disk, from which the chick develops. It is present on the yolks of all eggs whether fertile or infertile. The yolk always floats in the white with the chick spot on top. By this provision of



FIG. 1.—A stove pipe candle.

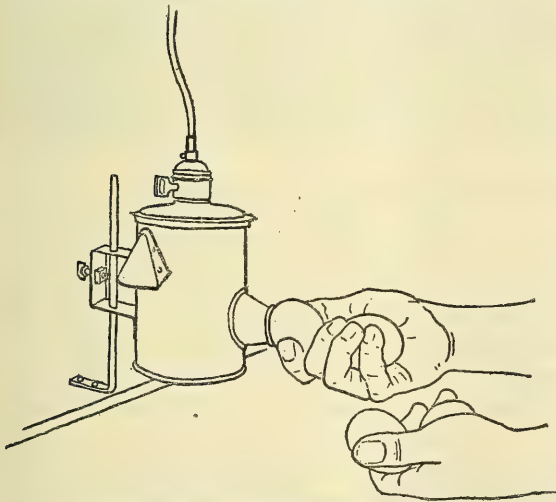


FIG. 2.—Method of holding eggs during candling.

nature, the developing chick comes nearest the body of the hen during incubation and on that account receives the most warmth.

Around the yolk, as indicated in figure 4, lies a small quantity of thin white; then comes a heavy layer of thick white; and outside of this another layer of thin white. Extending from the yolk through the white toward each end of the egg are

twisted, cordlike coils of an opaque white material called the chalazæ. These cords may be likened to hammock strings in that they serve to hold the yolk in position, yet allow it to turn freely. The chicken does not come from the chalazæ as is often supposed, but from the germinal disk. The white has a firm, gelatinous consistency, due to a network of interlacing fibers, which are so fine that they can

be seen only by the aid of a microscope. The beating of the egg white brings about the incorporation of air into this fine network of fibers.

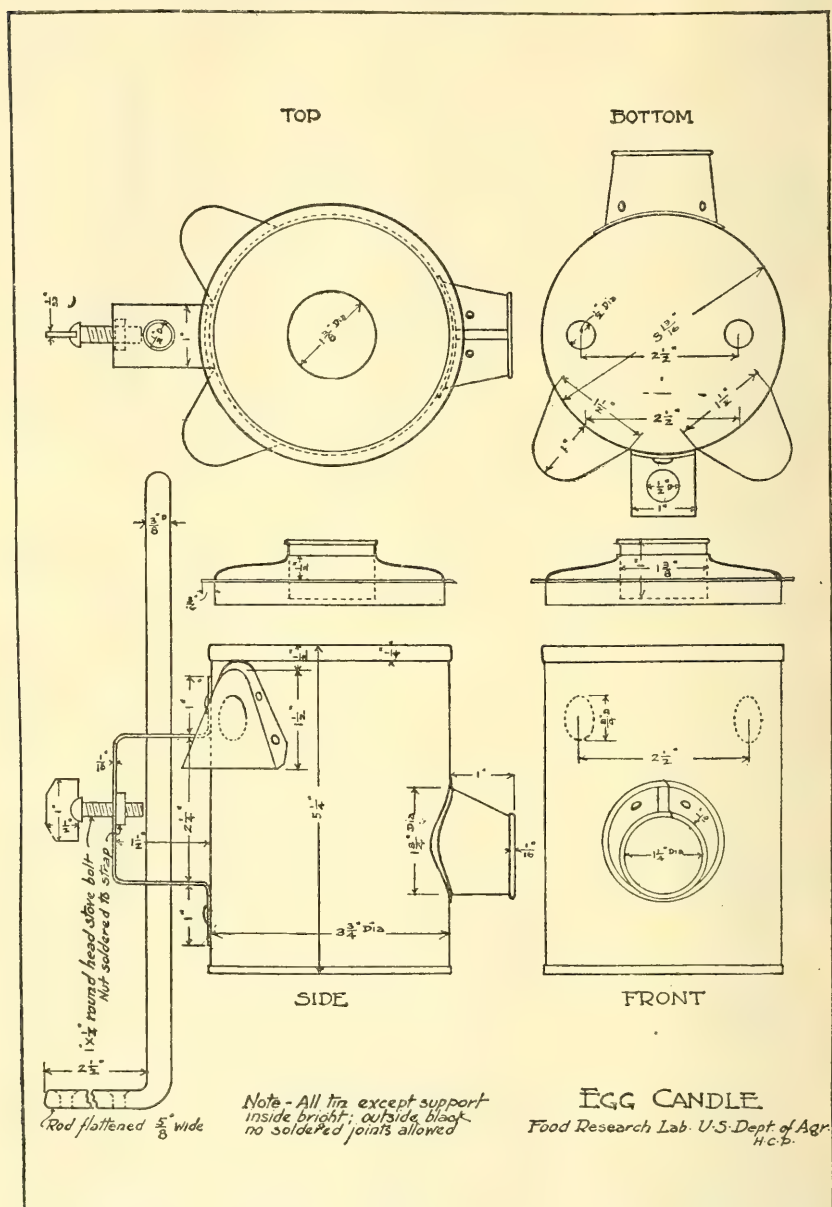


FIG. 3.—Working drawings for a one-hole spout candle. (Reproduced from Bul. 5, Missouri State Poultry Experiment Station and U. S. Department of Agriculture, Bureau of Chemistry.)

Between the white and the shell are two fibrous membranes. When the egg is first laid, the contents fill the entire shell. On cooling,



however, the contents shrink and the two membranes separate at the large end of the egg, forming an air space less than three-quarters of an inch in diameter. The outer or shell membrane follows the outline of the shell and is both tougher and thicker than the inner or egg membrane, which follows the outline of the egg contents.

The shell of the egg is porous and varies in color from white to dark brown, depending upon the breed of the hen laying it. The yolk is composed mainly of fat, protein, and water; the white, of protein and water. The yolk sac, shell membrane, and fibers in the white are made of keratin, a material similar chemically to finger nails or the horns or hoofs of animals. The shell is principally carbonate of lime.

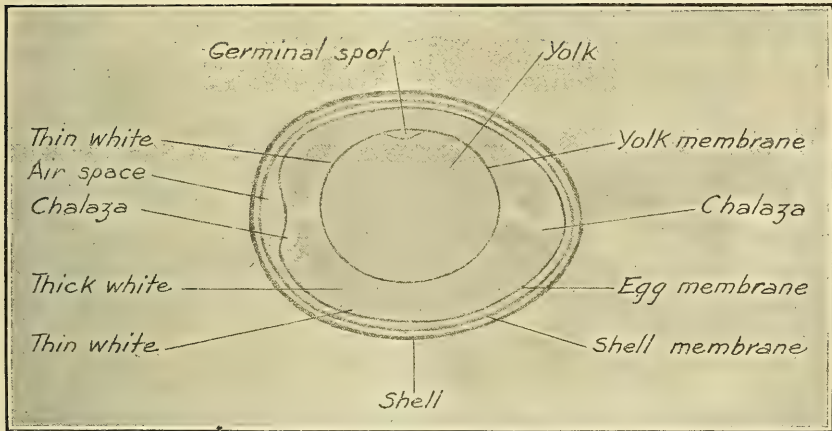


FIG. 4.—Structure of an egg.

#### HOW TO HOLD AN EGG WHEN CANDLING.

The room in which the candling is done must be dark. The egg is held by hand in a slanting position with the large end against the opening in the candle. A few moderately rapid twists are given to the right and to the left. During this turning, which should be enough to expose the entire surface of the egg to view, the size of the air cell and the condition of the white and yolk should be noted. After this movement the egg should be turned from end to end so that the whole of the egg is again seen. If the egg is not completely turned before the candle bad eggs, such as those containing mold spots or yolks stuck to the shell, may not be detected. In other words, one side of an egg may appear good on candling, but the other side may be found to be bad if brought into view.

It is customary to pick up two eggs in each hand, supporting one egg at a time in the tips of the thumb and the first two fingers (see fig. 2). Each egg should be candled separately. After the foremost egg in each hand has been candled, it is dropped back into the palm

and the other two eggs are brought forward by a dexterous movement of hand and palm, held before the light, and graded. The ability to shift two eggs in each hand makes for more rapid work and may be acquired by practicing with china eggs. A good deal of experience is required to shift eggs safely and quickly.

During candling the egg should come in contact with the fingers as little as possible, so that small blemishes such as mold spots will not be hidden from view. It is advisable not to hold more than two eggs in each hand during candling because of the added chance of breaking the eggs and confusing the grades.

Until the beginner has had some experience it will be advisable for him frequently to check the decision reached by candling with the appearance of the egg when broken into a saucer or other convenient receptacle.

### WHAT TO LOOK FOR IN CANDLING AN EGG.

The relation of the shell, air space, white, and yolk to grading by candling will be discussed separately before taking up the consideration of the different kinds of eggs. After the beginner has become acquainted with the different factors which influence the grading of an egg, it is a comparatively simple matter for him to recognize the predominating characteristics of each egg and to place the egg in its proper grade.

#### THE SHELL.

It is possible to grade eggs by inspection through the shell because of the partial transparency of the shell when held before a light in a dark room. The egg contents can be seen much more plainly through a white shell than through a brown one. The light shining through a white egg, on candling, is yellow, with a slightly pinkish tinge; that from a brown egg is much pinker; and that from a dark brown egg is almost red. In each instance, the color deepens in the region of the yolk. The contrast between the white and the yolk is much greater in white than in brown eggs. The appearance before the candle of a fresh white and a fresh brown egg is shown in Plates I and II. The beginner should study eggs with white shells first and postpone the study of eggs with brown shells until he has had some experience. Likewise he should begin with clean eggs, for the reason that dirt or stains on the shell may cast a shadow on the contents and thus render accurate candling difficult. Candling of eggs with mottled, warty, or uneven shells should also be deferred.

The colored sketches of the different kinds of eggs shown in this bulletin were made, with few exceptions, from eggs with white shells, and were selected to show as much of the interior as possible. The descriptions in most instances will apply to white eggs. These facts

should be taken into consideration when comparing the illustrations and descriptions with the appearance of eggs before the candle.

Candling will enable one to identify cracked eggs more accurately than will clicking. Therefore, when eggs are graded by candling to judge the quality of the contents, those with damaged shells can be removed at the same time. If there are a few small holes in the candle to shed light on the egg container below, dirty eggs can be picked out with but one handling of the eggs. Eggs with mold growing in the cracks are detected to some extent by candling, but much more readily away from the candle. (See Pl. IV, fig. 2.)

#### THE AIR SPACE.

The air space of a fresh egg is less than three-fourths inch in diameter, as may be seen by tilting an egg with the large end in front of a candle. As the egg ages the air space increases in size, owing to the evaporation of water from the liquid contents. The amount of evaporation depends very largely upon the age of the egg and the temperature at which it has been kept. In winter and spring eggs shrink more slowly than in summer. Therefore, the early spring eggs on the market will have smaller air spaces than the summer eggs. With continued shrinkage the egg membrane pulls away from the shell membrane at the air space, so that when the egg is turned before the candle the lower wall of the air cell changes at the same time. This condition is shown in Plate XI. In grading an egg the size of the air space is useful in determining its freshness. For example, a full egg will be graded as a "first" and a shrunken egg as a "second." Most bad eggs have enlarged air cells. The variations in the size of the air space of eggs of different grades are shown in Plates I and XII.

The egg membrane, which forms the lower wall of the air cell, may become broken by jars or jolts during the haul to market, or by severe shaking in the hand or other rough handling. When this membrane is broken the air cell always rises, irrespective of the position in which the egg is held, as may be seen from Plate IV, figure 1. Small bubbles of air frequently are seen when the egg is turned before the candle. When an egg becomes very stale the air in the air cell may move all the way around the egg between the two membranes. Such an air cell is termed "movable." Eggs with broken and movable air cells are graded as "seconds," if otherwise good, even though they may show no shrinkage.

#### THE WHITE.

The two factors to be considered when studying the white of an egg before the candle are its firmness and its color. A firm, thick white is found in a fresh egg, and a weak, thin white in a stale egg,



or in one which has been exposed to warm temperatures, as in summer or by incubation. The condition of the white is indicated on candling by the ease with which the yolk moves when the egg is rotated. For example, in a fresh egg the white is so firm that the yolk sways but little during candling, whereas in an egg with a weak white the yolk moves much more rapidly. A further indication of a thin white is seen on candling by the ease with which the white moves at the air cell, which usually is enlarged. Out of the shell the difference between a firm and a thin white is detected easily by pouring the egg from one dish to another. As an egg becomes stale the amount of thick white decreases and the amount of thin white increases.

Out of the shell the white of the fresh egg has an opalescent tinge, which characteristic is lost when an egg becomes stale. Eggs are found sometimes in which the white is as thin as water. Such eggs, however, are encountered rarely in ordinary candling. They are detected by the exceedingly rapid motion of the yolk when the egg is turned before the candle and by the very watery appearance of the white at the air cell, which usually is broken. The watery condition is caused, in most instances, by bacteria which penetrate the shell when it is broken or wet and grow in the egg material, destroying the mechanical structure of the white. When such eggs are opened the white flows out as readily as water and may be colorless, although usually it is a yellowish brown. The odor is bad and ammonia frequently is detected. Eggs with whites thus liquefied are inedible.

Several classes of bad eggs are indicated by discolored whites. Of these, eggs with yellow, bloody, moldy, and green whites are the most numerous.

A yellow white represents one of the most common forms of egg deterioration and is caused by the disintegration of the yolk. The whites assume a clouded yellow color before the candle, the depth of the color depending upon the amount of yolk present. (See Pl. VI.)

Eggs with bloody whites are comparatively rare. They occur most frequently among pullets' eggs in spring and fall and are caused by rupture of blood vessels of the hen during the passage down the oviduct of the egg before it is covered with the shell. The blood may be present in the egg in the form of clots attached to the yolk or distributed through the white. Such eggs are detected on candling by the red color of the white and by the clots which appear as irregular-shaped bodies floating in the egg. (See Pl. X.) If eggs with bloody whites are inclosed in white shells, the red color is detected easily by candling; if they are inclosed in brown shells, it is not so easy to distinguish between the deep pink color caused by the shell and the red color due to the presence of blood. An orange-colored yolk also may make it difficult to detect an egg with a bloody white.

Green-white eggs<sup>1</sup> are caused by bacteria which have penetrated a damaged or wet shell. These organisms grow in both the white and the yolk, producing in the former a very characteristic green color. Only in exceptional cases is the egg shell sufficiently transparent for the green color of the white to be seen by candling. Eggs with green whites represent one of the few kinds of bad eggs which can not be determined by inspection through the shell.

Mold may penetrate a wet, broken shell and attach itself to the inner surface in the form of irregular patches. If the growth takes place at low temperatures, the affected portions of the white are gelatinized. These mold spots appear as dark areas before the candle, and are seen easily if not covered with the fingers. (See Pls. IV and XII.)

Foreign bodies, such as meat spots, grain, gravel, or worms, may be included in the egg in its passage down the oviduct. Before the candle they appear as dark spots moving in the white.

#### THE YOLK.

The conditions to be noted when studying the yolk may be divided into two classes, namely, those relating to ordinary decay and those pertaining to changes taking place during hatching.

#### CHANGES IN THE YOLK DUE TO DECAY.

The condition of the yolk is one of the most important factors to be determined when judging the quality of eggs by candling. When a fresh egg is twirled before the candle the yolk is dimly seen as a dark and shadowy object moving slowly in the white. The more transparent the shell the more distinctly is the yolk seen. The yolk sac is so strong and the white so firm that the spherical form of the yolk is altered very little when the contents of the egg are set in motion by the turning during candling.

Because of the thinner condition of the white, the yolk of a stale egg is seen much more plainly on candling than that of a fresh egg. As the egg ages the yolk sac weakens, and since the white becomes thinner at the same time the outline of the yolk is seen to change when the egg is rotated. When such an egg is opened the yolk flattens out and often breaks. The differences in the strength of the yolk sac of eggs of varying degrees of freshness are indicated clearly in Plates I and III. If eggs which have weak yolks before the candle show whole yolks when opened, they are graded as good if no other cause for rejection is observed.

When the yolk of an egg is so weak that a shake in the hand causes it to break and mix with the white, the egg should be graded

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<sup>1</sup> Illustrated in color in U. S. Dept. Agr. Bul. 51, Pl. VIII.

as unmarketable, for during shipment it is very likely to become unfit for food. These eggs are difficult to grade accurately by candling. They are of such inferior quality, however, that in case of doubt they should be classed as inedible.

The yolk sac may so weaken that the yolk seeps or strains through into the white. In these eggs the yolk would appear whole before the candle, but it would be weak, and the white would have a cloudy, yellow color. Out of the shell the yolk will be seen to be flattened and sometimes mottled and the white to be streaked with yolk. Very close candling is required to detect these eggs, and since they are border-line eggs, in which further deterioration is very rapid, they should not be graded as marketable.<sup>1</sup>

The more common form of disintegration of the yolk takes place through the rupture in one or more places of the yolk sac and the mingling of the white and yolk. This mixing is commonly known as "addling." All degrees of addling may be found, from the egg in which the yolk is just beginning to mix with the white to the egg in which no vestige of white is seen. The eggs representing the early stage of mixing are called "mixed rots," and those representing the later stage, "white rots." Both are inedible.

Mixed rots are characterized on candling and out of the shell by the irregular mixture of white and yolk. Often one portion of the yolk shows more deterioration than another, a condition shown by a darkened area on candling and by whitish streaks out of the shell. (See Pl. VI.)

The characteristics noted for mixed rots are even more marked in the white rots. In these eggs the white assumes a general yellow appearance on candling and out of the shell. (See Pl. VII.)

The incrusting of the yolk is a characteristic form of deterioration among eggs with soiled shells which have been held in cold storage. Under certain conditions the bacteria enter the shell, liquefy the white, making it watery, and produce a coating or crust on the yolk. Before the candle the yolk appears to have dark, mottled areas. Such eggs are unfit for food.

The position of the yolk also must be taken into consideration when grading eggs by candling. In a fresh egg the yolk is slightly above the center in the large end of the egg. Although lighter than the white, it does not float against the shell because the chalazæ tend to hold it in a central position in the egg. As the egg becomes stale with age, and especially from exposure to heat, the white is weakened, thereby making it possible for the yolk to float near the shell. This condition indicates staleness if the egg shows shrinkage.

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<sup>1</sup> An illustration of an egg with a seeping yolk is published in U. S. Dept. Agr. Bul. 224, Pl. XVI.



As aging continues, the yolk may adhere slightly to the shell, but a quick twist of the egg may set the yolk free without breaking it. In such a case the egg is edible, but a very low grade. With further aging the yolk will stick to the shell so that it can not be separated without breaking the yolk sac, in which case the egg is classed as bad. (See Pl. XI.) When the yolk is thus broken, as may happen when the egg is turned quickly, the appearance of the egg before the candle is the same as that of a mixed rot. Again, the yolk may be adherent at one point and broken at another. These eggs deteriorate quickly into mixed or white rots.

Dampness may be another factor causing the yolk to stick to the shell. In this case molds penetrate the shells as far as the yolk, which becomes very heavily attached to the shell, as shown in Plate XII.

The color of the yolk affects the color of the light passing through the egg from the candle in much the same way as does the color of the shell. For example, an egg with a light-yellow yolk will reflect a pink-yellow light when held before the candle, and an egg with an orange yolk a red light. Sometimes eggs with olive-colored yolks are found. These reflect a green color from the yolk, which characteristic has given them the name of "grass eggs." (See Pl. V.) The color of the yolk is not considered in the grading of eggs by the candle, except in the case of "grass eggs," which are classed as "seconds," because their color is abnormal.

#### CHANGES IN THE YOLK DUE TO HATCHING.

A few hours' incubation under the hen or exposure to warm temperatures, as in summer, is sufficient to start the hatching of a fertile egg. In its early stages this condition can be detected on candling by the reddish glow of the area surrounding the germinal spot, which in this stage of development is termed a "hatch spot." This is very plainly seen when the egg is opened. A hatch-spot egg before the candle and out of the shell is shown in Plate III. An egg in which the hatching has progressed to this stage is considered edible but is graded as a "second."

Blood forms if incubation continues. At this stage in the development of the embryo, the egg is considered inedible. A fertile egg containing blood, due to hatching, is termed a "blood ring." Such eggs are detected on candling by the circle, or portion of a circle, of blood present around the reddish hatch spot area of the yolk. (See Pl. VIII.) If the embryo does not die, and conditions of incubation are favorable, the different stages of development from the forming of blood veins to the growing of the mature chick can be followed by observation before the candle. After the embryo chick begins to

take form it appears black on candling. (See Pl. IX.) An egg containing a large embryo can not be distinguished from a black rot, except by the absence of motion of the contents when the egg is turned during candling. Practically all incubated fertile eggs found in the candling of eggs for market contain dead embryos.

After the embryo has died the contents of the egg are subject to all the changes making for deterioration which have been described for the white and yolk. For example, a yolk bearing a blood ring may adhere to the shell or disintegrate and mix with the white. The yolk of a partially hatched egg usually attaches itself to the shell by the hatch spot or blood ring.

### CLASSIFIED DESCRIPTION OF EGGS BEFORE THE CANDLE AND OUT OF THE SHELL.

The different types of eggs found in commerce may be classified according to edibility and possibility of detection by candling as follows:

TABLE 1.—*Eggs classified according to edibility and possibility of detection by candling.*

#### EGGS THAT CAN BE DETECTED BY CANDLING.

| EDIBLE.                                   |                          | INEDIBLE.                                                        |                          |
|-------------------------------------------|--------------------------|------------------------------------------------------------------|--------------------------|
| Kind.                                     | Illustrated in Plate No. | Kind.                                                            | Illustrated in Plate No. |
| Fresh egg.                                | I, II                    | Black rot.                                                       | IV                       |
| Hatch-spot egg.                           | III                      | Egg with seeping yolk.                                           | VI                       |
| Stale egg.                                |                          | Mixed rot.                                                       | VII                      |
| Weak egg.                                 |                          | White rot.                                                       | VIII                     |
| Egg with movable air cell. <sup>1</sup>   | IV                       | Blood ring.                                                      | IX                       |
| Egg with double yolk. <sup>1</sup>        | V                        | Egg with large embryo.                                           | X                        |
| Egg with olive-colored yolk. <sup>1</sup> |                          | Egg with bloody white.                                           | XI                       |
|                                           |                          | Egg with slightly stuck yolk.                                    | IV, XII                  |
|                                           |                          | Egg with heavily stuck yolk.                                     |                          |
|                                           |                          | Moldy egg.                                                       |                          |
|                                           |                          | Egg with crusted yolk.                                           |                          |
|                                           |                          | Egg containing blood spots or other foreign bodies. <sup>2</sup> |                          |
|                                           |                          | Egg with heavily mottled yolk.                                   |                          |

<sup>1</sup> Edible if there is no deterioration.

<sup>2</sup> Sometimes edible on removal of body.

#### EGGS THAT CAN NOT BE DETECTED BY CANDLING.

| INEDIBLE.                                        |
|--------------------------------------------------|
| Kind.                                            |
| Egg with green white.<br>Musty egg.<br>Sour egg. |

A brief description of the appearance of each type of egg before the candle and out of the shell is given in the following pages. The principal distinguishing characteristics also are given. These tabulated descriptions, in conjunction with the table and the illustrations,

can be used as a working guide in the candling of eggs. The terms used to express the specific condition of the eggs are defined in the general description of shell, white, and yolk, as discussed on pages 6 to 12.

**FRESH EGG.<sup>1</sup>**

(Plates I and II.)

**BEFORE THE CANDLE.**

*Air space:* Not enlarged; less than three-fourths inch in diameter.

*White:* Firm and clear.

*Yolk:* Dimly seen through the white as a shadowy object indistinct in outline. The chick spot is not visible.

*Distinguishing characteristics:* No shrinkage and general firm conditions of white and yolk.

Edible.

**OUT OF THE SHELL.**

*White:* Firm and thick; opalescent; reflects the light.

*Yolk:* Spherical and firm; chick spot small with no sign of hatching. Color is uniform for the entire yolk, but varies in color from light yellow to deep orange, and is occasionally olive green.

*Distinguishing characteristics:* General firm condition of white and yolk. White, opalescent.

**HATCH-SPOT EGG.**

(Plate III.)

**BEFORE THE CANDLE.**

*Air space:* Usually enlarged.

*White:* Thin and clear.

*Yolk:* A distinct reddish glow around the germinal spot, which is visible; usually located above the middle of the egg.

*Distinguishing characteristic:* Reddish glow on the yolk.

Edible.

*Occurrence:* Chiefly during warm weather or hatching season.

**OUT OF THE SHELL.**

*White:* Thin and clear; no opalescence; does not reflect the light as strongly as does a fresh egg.

*Yolk:* Bears a hatch spot; is flattened, being especially weak around the embryo.

*Distinguishing characteristic:* Hatch spot on the yolk.

**STALE EGG.<sup>2</sup>****BEFORE THE CANDLE.**

*Air space:* Enlarged; the lower wall may be movable in outline.

*White:* Thin and clear.

*Yolk:* Definite in outline; sometimes weak, and may occasionally have dark, mottled areas.

*Distinguishing characteristics:* Enlarged air cell and increased contrast between white and yolk as compared with a fresh egg.

Edible.

*Occurrence:* Among eggs not marketed promptly.

**OUT OF THE SHELL.**

*White:* Thin; no opalescence; does not reflect the light as much as does a fresh egg.

*Yolk:* Flattened, and occasionally may have light, mottled areas.

*Distinguishing characteristics:* Thin white and flattened yolk.

<sup>1</sup> The color of a white egg before the candle is yellow with a pinkish tinge, that of a brown egg is pinker, and that of a dark brown egg is almost red. In each instance the color deepens in the region of the yolk.

<sup>2</sup> Illustrated in color in U. S. Dept. Agr. Bul. 51, Pl. III.



WEAK EGG.<sup>1</sup>

## BEFORE THE CANDLE.

*Air space:* Enlarged; lower wall usually movable in outline.

*White:* Very thin and clear.

*Yolk:* Whole, but very weak; may bear a hatch spot and may be mottled.

*Distinguishing characteristic:* A weak condition of white and yolk.

Edible.

*Occurrence:* Chiefly during summer.

## OUT OF THE SHELL.

*White:* Clear and very thin.

*Yolk:* Membrane often breaks when the egg is opened; may have a hatch spot and may be mottled.

*Distinguishing characteristic:* Yolk sac often breaks when egg is opened.

## EGG WITH MOVABLE AIR CELL.

(Plate IV, figure 1.)

## BEFORE THE CANDLE.

*Air space:* Always on top no matter in what position the egg is held.

*White and yolk:* Fresh, stale, or deteriorated.

*Distinguishing characteristics:* Movable air cell; much less contrast between white and yolk in a weak egg than in a fresh egg; gives a hollow sound when tapped against the shell of an egg with normal air cell.

## OUT OF THE SHELL.

*White and yolk:* Fresh, stale, or deteriorated.

*Distinguishing characteristic:* None.

Edible if contents have not deteriorated.

*Occurrence:* During autumn, when the proportion of stale eggs is the greatest, and in those sections where eggs are subject to rough handling.

## MOLDY CRACKED EGG.

(Plate IV, figure 2.)

For description see page 18.

## BLACK ROT.

(Plate IV, figure 3.)

## BEFORE THE CANDLE.

*Air space:* Very much enlarged; lower wall may be movable in outline or may be broken.

*Contents of shell:* Gray or black in color.

*Distinguishing characteristic:* Black color.

Inedible.

*Occurrence:* Most frequently during spring and late summer months.

## OUT OF THE SHELL.

The color of the mixture varies from gray-green to dirty yellow. It may contain a decomposed embryo.

*Distinguishing characteristic:* Discolored mixture with bad odor.

<sup>1</sup>Illustrated in color in U. S. Dept. Agr. Bul. 224, Pl. XIV.

## EGG WITH DOUBLE YOLK.

## BEFORE THE CANDLE.

*Air space:* Small or enlarged.

*White:* Fresh, stale, or deteriorated.

*Yolk:* Two yolks floating in the white.

*Distinguishing characteristics:*

Double yolk, and egg is usually very large.

Edible if deterioration has not taken place.

*Occurrence:* Infrequent.

## OUT OF THE SHELL.

*White:* Fresh, stale, or deteriorated.

*Yolk:* Two yolks.

*Distinguishing characteristic:* Two yolks.

## EGG WITH OLIVE-COLORED YOLK.

(Plate V.)

## BEFORE THE CANDLE.

*Air space:* Small or enlarged.

*White:* Fresh, stale, or deteriorated.

*Yolk:* Olive or greenish yellow in color.

*Distinguishing characteristic:* A greenish cast to whole egg, deepening in the region of the yolk.

Edible if deterioration has not taken place.

*Occurrence:* Most frequently in spring, but may be seen throughout the year.

## OUT OF THE SHELL.

*White:* Fresh, stale, or deteriorated.

*Yolk:* Olive or greenish yellow in color.

*Distinguishing characteristic:* Olive-colored yolk.

EGG WITH SEEPING YOLK.<sup>1</sup>

## BEFORE THE CANDLE.

*Air space:* Usually enlarged; the lower wall may be movable in outline.

*White:* Yellow, due to seepage of yolk through defective yolk sac.

*Yolk:* Very weak, and may show dark, mottled areas.

*Distinguishing characteristics:* Yellow white and uneven coloring of yolk if mottled.

Inedible.

*Occurrence:* A common form of deterioration during entire year.

## OUT OF THE SHELL.

*White:* Thin and partially or entirely streaked with yellow.

*Yolk:* Flattened and very weak, and may be mottled.

*Distinguishing characteristic:* Seeping yolk.

<sup>1</sup> Illustrated in color in U. S. Dept. Agr. Bul. 224, Pl. XVI.

**MIXED ROT.**

(Plate VI.)

**BEFORE THE CANDLE.**

*Air space:* Enlarged; the lower wall may be movable in outline.

*White:* Unevenly streaked with yellow; thin.

*Yolk:* Yolk sac broken in one or more places and contents flowing into the white. Dark areas may be seen in the liquid.

*Distinguishing characteristic:* Streaked appearance of contents due to mixing of white and yolk.

Inedible.

*Occurrence:* A very common form of deterioration during entire year.

**OUT OF THE SHELL.**

*White:* Thin and unevenly streaked with yellow.

*Yolk:* Broken and partially mixed with the white; may contain whitish streaks.

*Distinguishing characteristic:* Partially addled contents.

**WHITE ROT.**

(Plate VII.)

**BEFORE THE CANDLE.**

*Air space:* Enlarged; lower wall may be movable.

*White and yolk:* Mixed, giving general yellow color to contents.

*Distinguishing characteristic:* More or less uniform mixture of white and yolk.

Inedible.

*Occurrence:* A very common form of deterioration during entire year.

**OUT OF THE SHELL.**

*White and yolk:* Mixed together more or less completely. Has usually a stale or a sour odor.

*Distinguishing characteristic:* Addled appearance.

**EGG WITH BLOOD RING.**

(Plate VIII.)

**BEFORE THE CANDLE.**

*Air space:* Large or small.

*White:* Thin and clear.

*Yolk:* A distinct reddish glow on one side of the yolk, in which is seen a blood ring or portion of ring.

*Distinguishing characteristic:* Presence of blood in region showing reddish glow.

Inedible.

*Occurrence:* During warm weather or hatching season.

**OUT OF THE SHELL.**

*White:* Thin and clear.

*Yolk:* Germinal spot enlarged and surrounded by complete or partial blood ring; yolk flattened and often very weak.

*Distinguishing characteristic:* Blood ring on yolk.



## EGG WITH LARGE EMBRYO.

(Plate IX.)

## BEFORE THE CANDLE.

*Air space:* Enlarged.*White:* Thin and clear.*Yolk:* Covered with a network of blood vessels, in the center of which the embryo is beginning to take, or has taken, form. The embryo is seen as a dark body on the yolk, its size depending upon the period of incubation. With age, the blood vessels may become faded. The yolk may or may not be broken.*Distinguishing characteristics:*

The network of blood vessels and the dark body on the yolk, which usually is broken.

Inedible.

*Occurrence:* During the hatching season and during warm weather.

## OUT OF THE SHELL.

*White:* Thin and clear unless the yolk is broken.*Yolk:* Covered with a network of blood vessels, in the center of which is the body of the embryo. The yolk may or may not be broken.*Distinguishing characteristic:* Size of embryo.

## EGG WITH BLOODY WHITE.

(Plate X.)

## BEFORE THE CANDLE.

*Air space:* Small or enlarged.*White:* Red in color, very often containing clots of blood which occur as irregular-shaped bodies moving through the white.*Yolk:* Usually intact.*Distinguishing characteristic:* A general reddened appearance, particularly in the white.

Inedible.

*Occurrence:* Infrequent at all seasons of the year; most common in early spring and late autumn when pullets begin to lay.

## OUT OF THE SHELL.

*White:* Mixed with blood; sometimes clots are present.*Yolk:* Normal for grade of egg, but may bear blood clots.*Distinguishing characteristic:* Blood in white.

## EGG CONTAINING BLOOD CLOTS OR OTHER FOREIGN BODIES.

## BEFORE THE CANDLE.

*Air space:* Small or enlarged.*White:* Blood clots and foreign bodies appear as irregular-shaped dark-colored bodies floating in the white.*Yolk:* Usually intact.*Distinguishing characteristic:* Dark bodies floating in the white.

## OUT OF THE SHELL.

*White:* Pieces of flesh, grain, gravel, or even feces or worms may be attached to the yolk or floating in the white.*Distinguishing characteristic:* Blood clots or foreign bodies in the white.

Inedible, except in the case of eggs containing small clots of blood or small pieces of meat, which are easily removed when the egg is opened.

*Occurrence:* Infrequent.

## EGG WITH YOLK SLIGHTLY STUCK TO THE SHELL.

(Plate XI.)

## BEFORE THE CANDLE.

*Air space:* Enlarged; lower wall may be movable in outline.

*White:* Thin, may be streaked with yellow if yolk sac is ruptured.

*Yolk:* Attached to shell by a small area of the yolk sac; waves when egg is turned; as the yolk sac is weak, it frequently may be found to be ruptured, with contents flowing into the white, or twisting during candling may tear the yolk from the shell, when the appearance before the candle will be similar to that of a mixed rot. Occasionally, if the yolk has just begun to stick to the shell, turning the egg in front of the candle may free the yolk without breaking its sac, when it is graded as a good egg.

*Distinguishing characteristic:* The sticking of the yolk by a small area so that it sways easily when the egg is turned.

Inedible.

*Occurrence:* Very common in summer and autumn.

## OUT OF THE SHELL.

*White:* Thin and clear, or may be streaked with yellow if yolk is broken.

*Yolk:* If whole in the shell, it is broken when the egg is opened, leaving a yellow mark on the shell at place of contact. If yolk was both stuck and broken in the shell, it will have the appearance of a mixed rot when removed from the shell. If yolk was very lightly stuck it might drop out of the shell without breaking, in which case the egg would be classed as good.

*Distinguishing characteristic:* A broken yolk and a yellow mark on the shell where the yolk is stuck.

## MOLDY EGG.

(Plate IV, figure 2; Plate XII.)

## BEFORE THE CANDLE.

*Air space:* Enlarged; lower outline may be movable.

*White and yolk:* Mold shows as black or grayish areas inside shell. If egg is damaged, the growth follows the line of the crack. The growth may be confined to the shell, in which case the contents of the egg will appear normal; or it may be in the air cell or the white, in which case its presence is detected by dark-colored patches; or it may extend to the yolk, which in this stage is heavily attached to the shell and covered with dark spots. In an advanced stage of mold growth the whole egg may appear black.

*Distinguishing characteristic:* Black patches of mold growth.

Inedible.

*Occurrence:* Throughout the year among eggs held in damp surroundings.

## OUT OF THE SHELL.

*White and yolk:* Normal, if the mold growth has not extended beyond the shell. If the mold is growing in the white it is seen as small patches on the shell, and the yolk may be whole but is usually weak. Sometimes the shell is colored blue or red by the mold growth. If the mold has invaded the yolk so that it sticks to the shell, it then has the appearance of an egg with a heavily stuck yolk.

If the mold growth has taken place in cold temperatures, the infected areas will be gelatinous.

*Distinguishing characteristic:* Infected areas either dark in color or gelatinized.

**EGG WITH HEAVILY STUCK YOLK.<sup>1</sup>****BEFORE THE CANDLE.**

*Air space:* Enlarged; lower wall may be movable in outline.

*White:* Very thin.

*Yolk:* Stuck to the shell by a large area of the yolk sac and does not wave when the egg is turned; the color at point of contact is very much darkened.

*Distinguishing characteristics:*

Firm attachment of yolk to shell and dark color at place of contact.

Inedible.

*Occurrence:* Throughout the year among eggs held in damp surroundings.

**OUT OF THE SHELL.**

*White and yolk:* More or less mixed together; a large portion of the yolk remains attached to the shell.

*Distinguishing characteristic:* Heavily adherent yolk.

**EGG WITH HEAVILY MOTTLED YOLK.****BEFORE THE CANDLE.**

*Air space:* Small or enlarged.

*White:* Usually weak.

*Yolk:* Bears dark mottled areas and is frequently weak.

*Distinguishing characteristic:*

Dark mottled areas on yolk.

Inedible.

*Occurrence:* Chiefly among summer eggs and eggs held at low temperatures.

**OUT OF THE SHELL.**

*White:* Usually weak.

*Yolk:* Streaked with different shades of yellow; sometimes watery areas are present.

**MUSTY EGG.****OUT OF THE SHELL.**

*White:* Fresh, stale, or deteriorated.

*Yolk:* Stale or deteriorated.

*Distinguishing characteristic:* Musty odor.

Inedible.

*Occurrence:* Among eggs held in damp surroundings.

**SOUR EGG.****OUT OF THE SHELL.**

*White:* Thin, and is frequently cloudy.

*Yolk:* Weak and often broken.

*Distinguishing characteristic:* Sour odor.

Inedible.

*Occurrence:* During entire year.

**EGG WITH GREEN WHITE.****OUT OF THE SHELL.**

*White:* Clear and distinctly green in color.

*Yolk:* Flattened and sometimes very weak.

*Odor:* May or may not be pleasant.

*Distinguishing characteristic:* Green white.

Inedible.

*Occurrence:* Throughout the entire year, but chiefly in spring among dirty, washed, and cracked eggs, when the weather is damp.

<sup>1</sup> Illustrated in color in U. S. Dept. Agr. Bul. 224, Pl. XV.



## EGG WITH CRUSTED YOLK.

## BEFORE THE CANDLE.

*Air space:* Enlarged, usually broken.

*White:* Decidedly watery and frequently yellowish in color.

*Yolk:* Crusted and weak.

*Distinguishing characteristics:*

Watery condition of white and dark spots on yolk.

## OUT OF THE SHELL.

*White:* Extremely watery and usually yellowish in color.

*Yolk:* Covered with a light colored crust, which has a tendency to flake off.

*Odor:* Putrid, frequently resembling ammonia.

*Distinguishing characteristics:*

Crusted yolk and watery white.

Inedible.

*Occurrence:* Chiefly among dirty and washed eggs held in cold storage.




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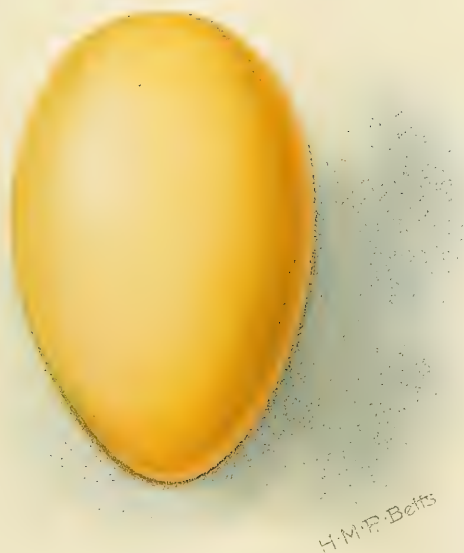


H.M.P. Betts

A FRESH EGG WITH WHITE SHELL BEFORE THE CANDLE AND OUT OF THE SHELL

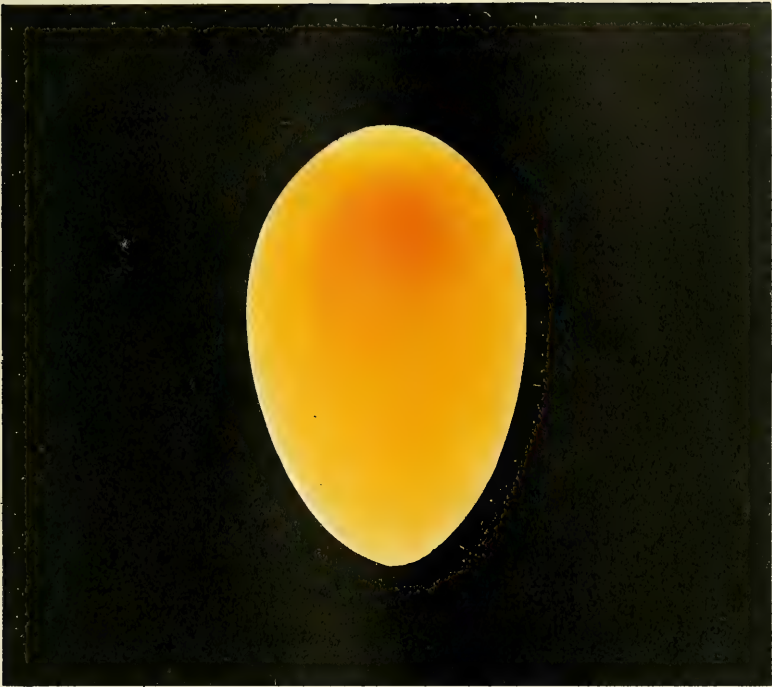






MEDIUM BROWN SHELL FRESH EGG IN DAYLIGHT AND BEFORE THE CANDLE



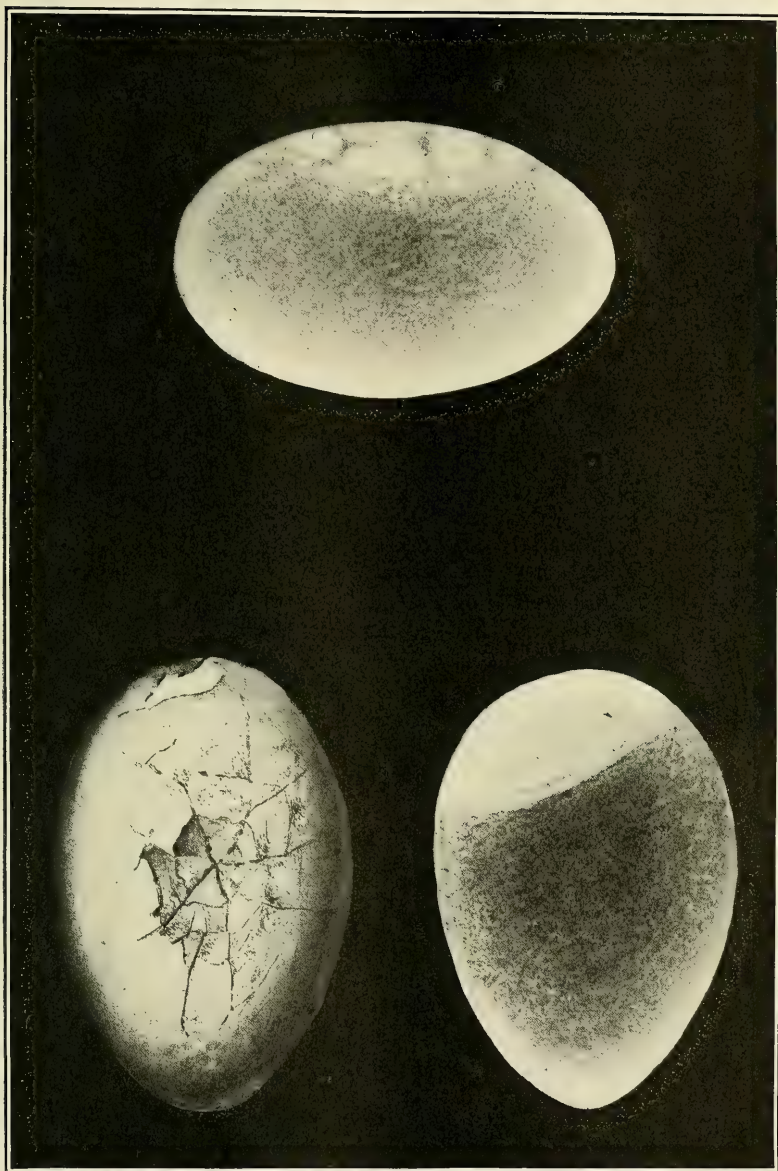


H.M.P. BOLT

HATCH SPOT EGG BEFORE THE CANDLE AND OUT OF THE SHELL







UPPER FIGURE: EGG WITH MOVABLE AIR CELL BEFORE THE CANDLE. LOWER: LEFT, MOLDY CRACKED EGG IN DAYLIGHT; RIGHT, BLACK ROT BEFORE THE CANDLE.







EGG WITH OLIVE COLORED YOLK BEFORE THE CANDLE AND OUT OF THE SHELL



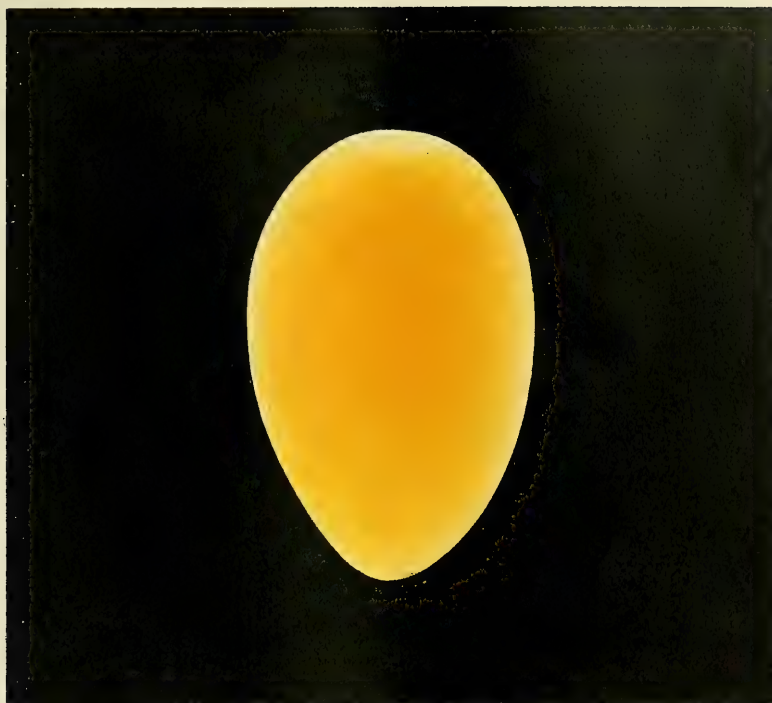


H.M.P. Betts

VALUED ROT BEFORE THE CANDLE AND OUT OF THE SHELL







H.M.P. Betts

WHITE ROT OR ADDLED EGG  
BEFORE THE CANDLE AND OUT OF THE SHELL



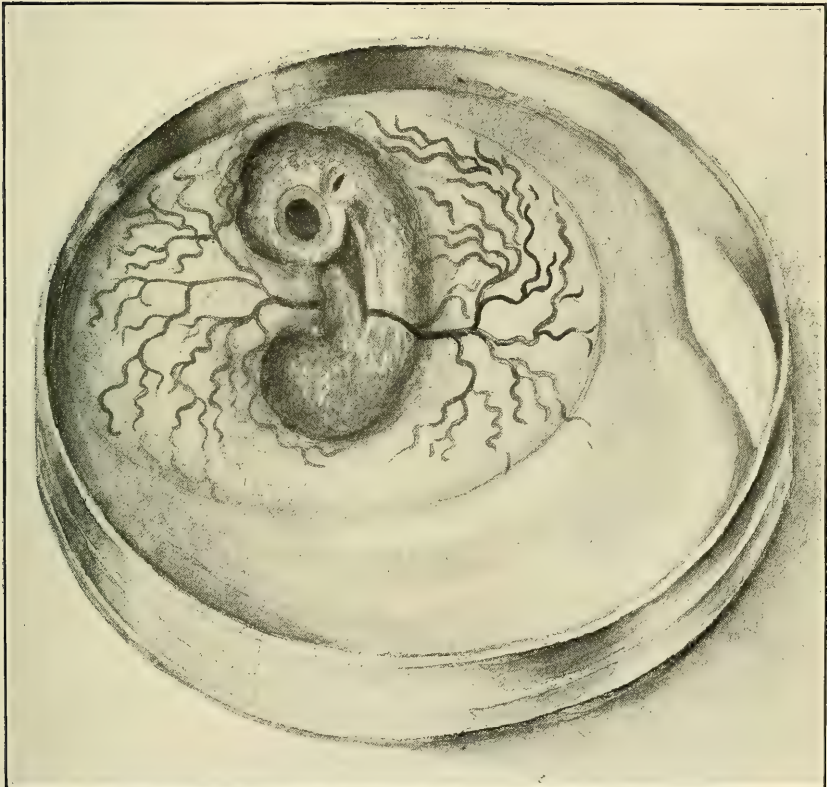




H.M.P. Bertr

EGG SHOWING "BLOOD RING"  
BEFORE THE CANDLE AND OUT OF THE SHELL





EGG WITH LARGE EMBRYO BEFORE THE CANDLE AND OUT OF THE SHELL.





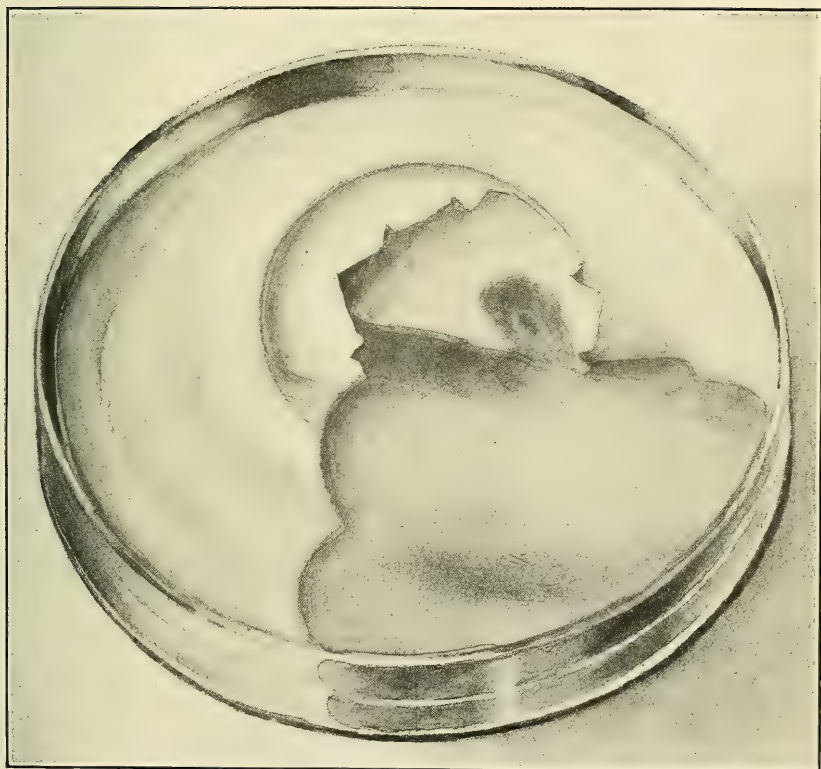
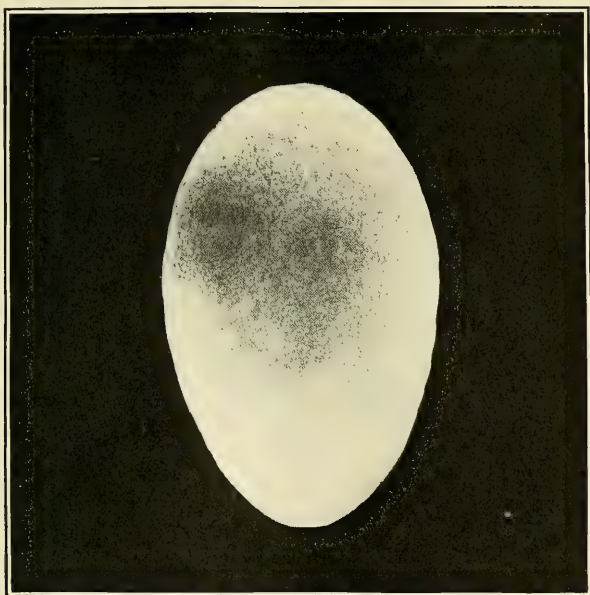


H.M.P. Belts

EGG WITH BLOODY WHITE BEFORE THE CANDLE AND OUT OF THE SHELL

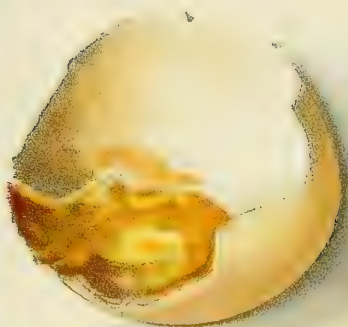
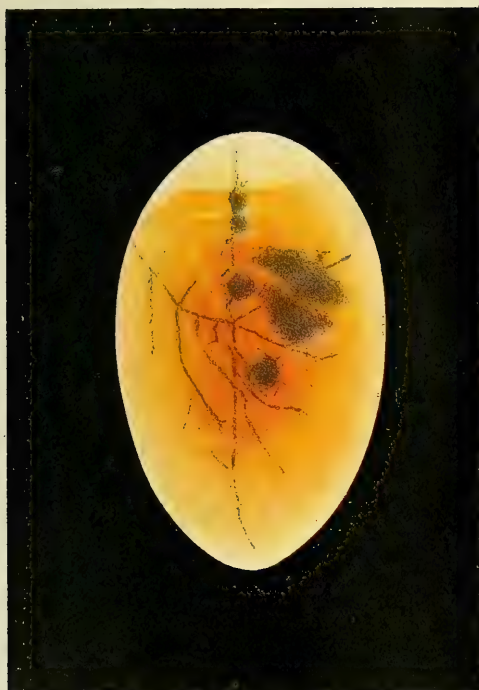






EGG WITH YOLK SLIGHTLY STUCK TO THE SHELL BEFORE THE CANDLE AND OUT OF THE SHELL.





H.M.P. Betts

MOLDY CRACKED EGG WITH DETERIORATED CONTENTS  
BEFORE THE CANDLE AND OUT OF THE SHELL







## BULLETIN No. 566

Contribution from the Bureau of Entomology  
L. O. HOWARD, Chief



Washington, D. C.



June 18, 1917

THE EUROPEAN EARWIG<sup>1</sup> AND ITS CONTROL.By D. W. JONES, *Scientific Assistant.*

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The European earwig (fig. 1) was first noted at Newport, R. I., in 1911 and is now present there in vast numbers. While it is not



FIG. 1.—The European earwig (*Forficula auricularia*): Adult males at left, adult females at right. (Original.)

considered of great economic importance in Europe, it has increased so rapidly in Newport that it has become a serious pest and caused

<sup>1</sup> *Forficula auricularia* L.

NOTE.—The first visit to Newport to study the habits of this insect was made by the writer in August, 1915. Eight trips of this kind, averaging four days each, were made during the summer and fall. Work was resumed May 6, 1916, and experiments were under close observation through the entire season. Mr. T. Suffern Tailer, a resident of Newport, whose grounds are in the heart of the area infested by this insect, gave financial support to cover expenses of the control measures and furnished the writer a large room to be used as a laboratory. With his cooperation and the help of his head gardener, Mr. William Edward, many facilities for the study of this insect were provided. Cooperation was also secured from other owners and gardeners, and Mr. Perez Simmons, a graduate of the Massachusetts Agricultural College, assisted in the application of control measures. The photographs used were made by Mr. Harold A. Preston of the Gipsy Moth Laboratory.

much annoyance. It is not unreasonable to suppose that this insect will spread to other sections of the country and cause great annoyance to farmers.

A much smaller colony, which, however, has increased rapidly, was reported from Seattle, Wash., in 1915. Other reports of the occurrence of this earwig in the United States appear to have originated from one or two cases in which isolated specimens were captured on imported plants.

This earwig is found all over Europe, but is seldom present in extreme numbers. It is impossible to say from which of the European countries the colony at Newport originated, or how the first individuals were imported. Quantities of nursery stock arrive from abroad each year upon which the importation may have been made.

### DESCRIPTION AND SEASONAL HISTORY.<sup>1</sup>

#### THE EGG.

The female earwig lays from 50 to 90 shining white eggs (fig. 2) in the ground, the eggs being about one-twentieth inch in length.

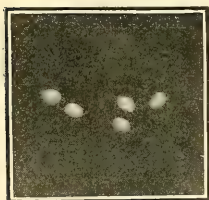


FIG. 2.—Eggs of European earwig. Enlarged twice. (Original.)

Forty females were mated and placed in separate cans of soil for observation. One deposited 82 eggs between November 6 and 10. On December 26 a second examination showed that 30 of the females (75 per cent) had deposited eggs. These females do not die at once, but hibernate, and in the spring attend the larvæ in their early stages. During the previous year in a few cases eggs were deposited in the spring, but failed to hatch.

Mellow garden soil with a southern exposure is a favorite place for egg deposition. Many hibernating females and their eggs have been found from 2 to 3 inches below the surface of the lawns.

#### THE LARVA STAGES.

The young earwigs, or larvæ, may be found in the ground, or at night on the soil surface, about May 5. They resemble the adults in general form, but have no wings and only delicate, simple forceps or pinchers on the posterior extremity of the body. At first they are pure white, but the color slowly darkens to a delicate olive green which has a peculiar shiny appearance. About June 9 they appear very dusky olive green, or even steel gray, with almost transparent

<sup>1</sup> The season during which these notes were gathered was rather peculiar. The entire spring was so cold and wet that foliage and insects were retarded in their development approximately one week. The summer was nearly normal, but was followed by a long dry fall. No killing frost occurred until the second week in November, and no real freezing of the soil took place until after December 1. The larval development in an ordinary season would be approximately one week ahead of the dates given for 1916, while the fall dates for hibernation and egg deposition usually would be from one to four weeks ahead of those in 1916.



legs and a dull-brown head (fig. 3). There are four larva stages which gradually approach the adult in size and color. The change from the fourth larva stage to the adult form takes place about July 18.

When first hatched the larvæ leave their underground nests, most noticeably on warm nights about two hours after dark. They swarm over the ground, but usually stay within 2 or 3 feet of the entrance to their nest. On cold nights few can be found. As they grow older they are active even on cold, wet nights.

Young larvæ feed on very tender green shoots such as clover and grass, and possibly portions of grass roots. Later they feed extensively on green shoots such as Lima-bean (fig. 4) or dahlia plants (fig. 5 in comparison with fig. 6). By July 1 dahlia buds begin to appear and the blossoms of sweet William and early roses are plentiful. These are damaged greatly by the young earwigs. The bases of the petals and the stamens are eaten and the old taste for green shoots disappears if favorable flowers are near.



FIG. 3.—Larva of European earwig. Enlarged twice. (Original.)



FIG. 4.—Lima bean plant partially eaten by young earwigs. (Original.)

#### THE ADULT.

The adult is rich reddish brown, with the wing covers and legs dull yellow brown, and the wings completely developed. From head

to tip of forceps it is about three-fourths of an inch in length. The forceps of the male are curved into a semicircle, or slightly elongated, with a tooth at the point of divergence. In the female the forceps are nearly straight.

The adults feed almost entirely on the petals and stamens of flowers, although many other kinds of food, such as clover, grass, terminal buds of chrysanthemums, and other fall flowers, are eaten. They kill and eat certain unprotected, sluggish larvæ, dead flies, and the dead or dying of their own species.

In late summer the adults congregate in large numbers in crevices or behind vines (fig. 7), near a good food supply. This concentration of large numbers of earwigs in favorable hiding places is due entirely to the mating instinct.



FIG. 5.—Dahlia plant defoliated by young earwigs.  
(Original.)

lawns. In some cases, as has been explained, they deposit eggs just before hibernating, so that this insect passes the winter in both the egg and adult stages.

Emergence from hibernation is dependent on the temperature. In 1916 females did not leave their hibernation quarters until the last week in April.

No migration appears to occur in the spring, except individual search for food. Apparently only a very small percentage of the total number of adult females is able to live over winter successfully.

#### HIBERNATION.

Adult males seldom live over winter in Newport, R. I. Nearly all of them die after copulation, which occurs in the fall, before cold weather sets in. An occasional male is found in the ground with a female in the late fall; these males usually die before spring.

Adult females hibernate in the ground from 2 to 8 inches below the surface. Any well-drained soil is suitable, either in gardens or under the sod of the

**DISAGREEABLE HABITS OF CONCEALMENT.**

The adult earwigs hide very quickly if disturbed by a sudden light or some unusual noise. During the day they hide in any crevice, fold of clothing, or even behind a convenient leaf which offers protection. Thus one finds them in large numbers on the porches, behind the chair cushions, under the rugs, and in folds of awnings. On one estate, each morning when the porch awnings were let down, over a quart of earwigs dropped out and were swept up and burned. The writer has seen at least 300 adult earwigs in one of the servants' halls at Newport. They were behind the cushions in the chairs, in



FIG. 6.—Normal, uneaten dahlia plant. (Original.)

folds of lace curtains, and even on the table. Bedrooms and bathrooms of the finest houses may be invaded by occasional adults in spite of careful watchfulness and screens. They are decidedly repulsive when found crawling rapidly over the walls or furniture at night. The stories about bodily harm done by these insects are all without foundation.

**AREA INFESTED.**

The evidence at hand regarding the area infested previous to 1914 is very meager. It consists of data drawn from conversations with



gardeners of the various estates. In almost every case they are men of education and trained powers of observation.

1911.—Mr. T. Suffern Tailer owns the estate where the first earwigs were noted. His gardener believes that a very few were present in 1911.

1912.—Mr. Tailer and his gardener state definitely that earwigs were present in 1912. Specimens were sent to Washington, D. C., by Dr. A. E. Stene, of the Rhode Island State College.

1913.—The infestation in 1913 had spread to adjoining estates. Large numbers were found on Mr. Tailer's estate and his men attempted certain control measures.

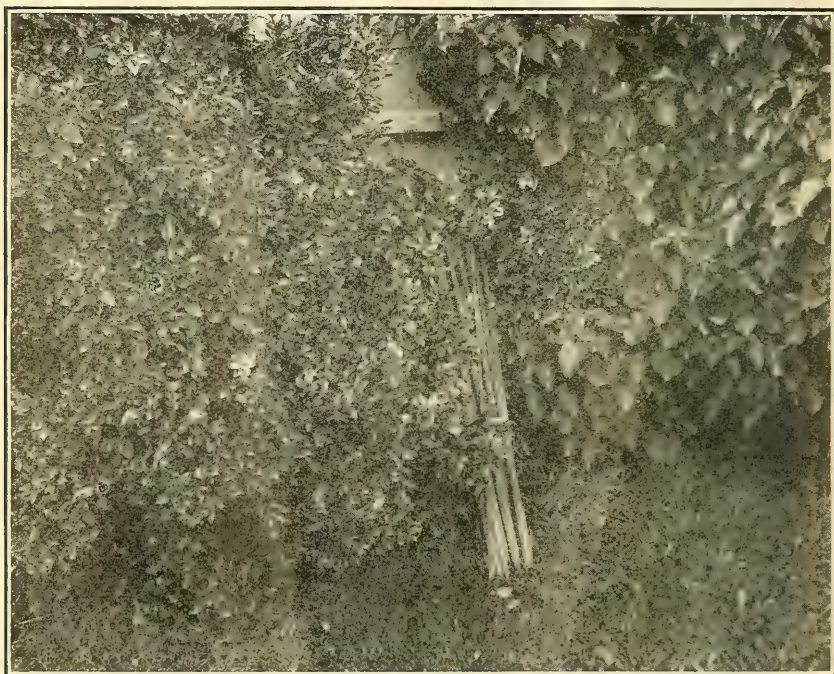


FIG. 7.—A typical congregating place for adult earwigs. (Original.)

1914.—About 1 square mile was heavily infested in 1914. Mr. Richard Gardener, of Newport, wrote to the Bureau of Entomology at Washington, asking for information regarding the insect.

1915.—The infestation during 1915 was so heavy that letters requesting information about methods of control were sent to Washington and to the State college at Kingston, R. I. A careful scouting conducted by the writer showed that about 9 square miles were heavily infested. This area is bounded on three sides by water. On the fourth side, 2 miles of territory in addition to that infested in 1915 had small scattered colonies. One isolated colony was located

about  $6\frac{1}{2}$  miles northeast of this infested area, on the estate of the late Alfred Gwynn Vanderbilt, of Portsmouth.

1916.—About 10 square miles were heavily infested in 1916 and many new small colonies were found outside of this area. The small colonies of the previous year showed considerable growth. In some cases hundreds of earwigs were present on estates where only a few were found the year before.

### METHODS OF DISPERSION.

This species rarely if ever spreads by flight; in fact, experimental efforts to induce these insects to use their delicate and complex wings were unsuccessful.

Many cases have been noticed where adult earwigs have been carried long distances in folds of clothing. Visitors to Newport may spread the insect to near-by cities in this way. Several isolated colonies located at a distance from the main infestation are at points where automobiles frequently stop while their owners walk about the extensive grounds.

These insects may be spread while hiding in the packing material or the soil of shipments of plants and general nursery stock. One dead specimen was found by J. J. Pillsbury, assistant State entomologist of Rhode Island, in a shipment of plants from Holland. The writer has noted these insects in the fall between the toes of dahlia bulbs.

### NATURAL ENEMIES.

A parasitic, threadlike worm has caused the death of approximately 10 per cent of the earwig larvæ under close observation in the laboratory. This worm<sup>1</sup> lives free in the body cavity of full-grown larval and adult earwigs. The average measurements of five of these parasites was  $3\frac{1}{4}$  inches by  $\frac{1}{8}$  inch.

Various other parasites are reported as having been reared from this species of earwig in Europe, but at Newport those so far dissected have been free from parasites except in the case of one small unidentified larva and the worm just referred to.

Toads eat earwig larvæ readily, but are not common at Newport.

Hens devour adult earwigs ravenously. One hen ate 10 of these insects thrown to her in as many seconds. Under natural conditions these insects are hidden away so carefully through the day that fowls can hardly be considered as economically important in the sense of controlling the insect.

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<sup>1</sup> *Filaria locustae*.

## CONTROL OF THE EARWIG.

### NEED FOR SPECIAL CONTROL MEASURES.

In Europe this insect appears to be held in check by parasites and other natural agencies, and it is very rarely present in large numbers. Gardeners who raise prize dahlias, chrysanthemums, and flowers of that class are the only ones who consider the earwig an actual pest. As a result control measures have developed slowly. Their aim has been simply to protect a small area from the depredations of a comparatively small number of earwigs. Various methods of trapping have been developed which satisfy the need, so no better methods have been worked out.

At Newport, as has been stated, this insect occurs in vast numbers. The lack of parasites and other natural enemies, together with the favorable conditions met with at every stage of the life history, has made this rapid increase possible.

The control measures offered in this paper have been developed through laboratory tests and later have been tested in field trials on a large scale.

### POISONED BAIT.

For early spring control, May 15 to June 15, poisoned-bread bait has proved extremely effective. In fact, it gave far better results than any other mixture that was tried. This method would prove cumbersome and expensive for the average farmer, but its extreme effectiveness makes it the best to recommend at this time. Stale bread was secured in 1916 for approximately 2 cents per pound. The bait is prepared as follows:

|                        |          |    |
|------------------------|----------|----|
| Stale white bread..... | pounds.. | 16 |
| Paris green.....       | pound..  | 1  |
| Water.                 |          |    |

Grind the bread up fine in a meat-chopping machine and mix the Paris green with it while dry. Stir the mixture thoroughly, slowly adding water enough to make a mixture which will run through the fingers, and one which, when thrown broadcast with some force, will break up into small particles. The addition of cheap honey to the mixture increases its effectiveness, but is not necessary.

This bait should be spread broadcast between dusk and 9 p. m. in gardens and on lawns near vines and shrubs. It should be thrown with considerable force in order to break the bait up into smaller pieces. If the infestation is heavy or was heavy the previous year, three applications covering about 10 days may be necessary. Warm evenings should be selected if possible, as on such nights the larvæ are more active.



## SONG BIRDS AND THE POISONED-BREAD BAIT.

The danger to song birds from the poisoned bread is very slight in the spring. After the 1st of July, especially in dry seasons when worms are not plentiful, this danger probably would increase. On May 11 an attempt was made to see if song birds would feed on this poisoned-bread bait. A narrow, recently spaded garden was selected which was south of a small greenhouse and east of a high privet hedge, where various birds were plentiful. Bits of this poisoned bait, the size of a pea, were placed 2 feet apart and 4 inches from the grass border, around the entire edge of the garden. The next morning the writer seated himself inside the greenhouse before daylight and watched the birds from 3.15 until 5.45 a. m. Ten robins were noted hopping along parallel to or crossing the lines of bait. They confined themselves entirely to feeding on earthworms. A pair of chipping sparrows were feeding on the soil surface nearly all the time, and a pair of purple grackles stalked across the lines of poisoned bait. In no case did these birds pay the slightest attention to the conspicuous bits of green bread, and after two days none of the particles were missing. No such experiment was tried in the late summer when worms were less plentiful. Probably it would be dangerous to use this mixture on ground where hens had free range.

## POISON SPRAYS.

Poison sprays are not effective after July 1 because of the habit developed by this insect of feeding on protected parts of flowers and the very new shoots of various plants. During the early stages, when larvæ concentrate their feeding on certain varieties of plants, these plants should be sprayed with arsenate of lead, 6 pounds to 50 gallons of water, care being taken that the young leaves especially are covered.

As this insect is known to feed somewhat on grass and clover it might be advisable to spray infested portions of lawns carefully with arsenate of lead, but more tests are necessary to show the effectiveness of this treatment.

## CONTACT SPRAYS.

Contact sprays which would burn foliage or would be objectionable near the houses on account of their odor were discarded. Any spray used on plants when they are in full bloom tends to make the petals of the blossoms fall. A contact spray which has given very good results in experimental work at Newport is made as follows:

|                                     |                |    |
|-------------------------------------|----------------|----|
| Soft potash soap-----               | ounces--       | 30 |
| Water -----                         | do-----        | 96 |
| Nicotine sulphate, 40 per cent----- | teaspoonfuls-- | 20 |

Dissolve the soap in a little of the water over a fire, then add the rest of the water and the nicotine sulphate. This makes 1 gallon of stock solution at an approximate cost of 50 cents. Use 1 part to 22 of water.

|                                     |                |               |
|-------------------------------------|----------------|---------------|
| Common laundry soap-----            | pound--        | $\frac{1}{2}$ |
| Water -----                         | gallons--      | 4             |
| Nicotine sulphate, 40 per cent----- | teaspoonfuls-- | 5             |

The soap must be shaved fine and dissolved in about one-third of the water, then the rest of the water and the nicotine sulphate are added. This mixture is applied without further dilution and is therefore practical only on a small scale. It does not give as good



FIG. 8.—Flowerpot traps for earwigs. Shorter supporting stakes proved to be of advantage. (Original.)

results as that containing potash soap. Fish-oil soap also was tried in this formula but burned foliage after several applications.

The foregoing two, being contact sprays, must actually hit the insects and hit them well or death is not assured. For this reason thorough spraying must be done at night, the insects being hit with a *fine mist* as they crawl over the plants, vines, and grass. To supplement this night spraying it is well to treat with a stream of the same material any crevices where insects are plentiful through the day. If necessary, the spraying of heavily infested areas should be repeated at intervals of three nights until the results are satisfactory.

#### TRAPPING.

Trapping is the chief method of control recommended by European authorities. The best trap (fig. 8) appears to be a 3-inch

flowerpot, with excelsior in the bottom, inverted over a 9-inch stick set in the ground close to plants or vines where earwigs are most numerous. The earwigs hide in the excelsior and should be shaken into a pail of water which has a thin film of kerosene oil on its surface. Pieces of bamboo, piles of straw, strawberry boxes, and in fact anything that offers shelter may be used; but these substitutes are either less effective or less easily handled than flowerpot traps.

#### MISCELLANEOUS.

In cases of extreme abundance earwigs may be kept from a porch by surrounding the porch completely with a 1-inch band of a suitable sticky substance. This sticky material prevents the invasion of earwigs unless some crevice exists under the band or some vine furnishes a bridge over it. To be effective this material should be applied by June 15, and its surface must be brushed over with a wire brush by July 15, and possibly once more during the season.

#### EFFICIENCY OF CONTROL MEASURES.

Experiments in the field with poisoned-bread bait in May were on a rather small scale. Several flower beds and small isolated lawns which were literally swarming with young earwigs were treated with this bait. The results were surprising. Very nearly 100 per cent of the larvæ were killed with one application of bait in each case.

Five estates were partially treated with this bait on June 22, 1916, and again three days later. The young earwigs at that time were passing rapidly into the fourth stage. As has been stated, the habits rapidly become similar to those of the adult. At this late date flowers such as sweet William and roses furnished food, and many of the earwigs had left their nests in the ground. Thus they were harder to reach with the poisoned-bread bait. It is estimated that over 75 per cent of the larvæ on these five estates were killed by these two late applications of bait. Far better results could be expected earlier in the season on favorable nights.

Spraying with contact sprays at night was done on a large scale after July 1. Mr. Simmons and an assistant used a barrel pump for this work, equipped with a Bordeaux nozzle. They planned to spray every three nights the same area, namely, the vines near the houses, and a 10-foot circle of lawn around each house. In this way the houses were kept free from the insect. This spraying was continued for over a month, although far less than 1 per cent of the usual number of earwigs could be found on these estates after July 20. A few continued to crawl in from surrounding estates, especially late in the fall.



Six flowerpot traps were placed near some dahlia plants throughout the season. These gave good results; but they are valuable only where the earwigs are scarce. They take care of the "crawl-in" after a garden has been treated with poisoned bait and contact spray.

Sticky substance was applied around the porches of one house. This is necessary only in extreme cases where no control measures have been applied and adult earwigs are causing annoyance in the houses.

#### SUMMARY OF RECOMMENDATIONS FOR CONTROL.

MAY 15 TO JUNE 15.

Spread poisoned-bread bait broadcast over the lawns and gardens. Select a warm evening about May 15 and apply the bait just before dark. Give one or two more applications of this bait at intervals of three or four nights.

Spray plants which show signs of having been eaten, using 6 pounds of arsenate of lead to 50 gallons of water, and being very careful to cover the young leaves with the spray.

AFTER JULY 1.

If the earwig has not been controlled in the spring, spray at night with a contact spray, covering the insects well as they crawl over the grass and plants. Repeat every three nights until the numbers are sufficiently reduced.

To supplement the night spraying look for crevices where earwigs commonly hide through the day. Squirt contact spray into these cracks every other day.

Place flowerpot traps every 10 or 12 feet along borders or near vines. Remove earwigs from the traps each day by shaking the excelsior over a pail of kerosene and water.

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## UNITED STATES DEPARTMENT OF AGRICULTURE



## BULLETIN No. 567



Contribution from the Forest Service  
HENRY S. GRAVES, Forester

Washington, D. C.

PROFESSIONAL PAPER

October 2, 1917

## INCREASED YIELD OF TURPENTINE AND ROSIN FROM DOUBLE CHIPPING.

By A. W. SCHORGER, *Chemist in Forest Products*, and R. L. PETTIGREW,  
*Assistant Engineer in Forest Products.*

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### MORE NAVAL STORES FROM THE SAME TREE.

Naval-stores operators have the chance to get 31 per cent more turpentine and 36 per cent more rosin from their trees by increasing the number of chippings during a season. This has been determined by actual experiments made by the Forest Service on a tract in Mississippi, the results of which are presented in this bulletin. Briefly, the method that gives the increased yields is to chip twice a week instead of once. At the same time, the streaks are cut only one-fourth inch high instead of one-half inch, the present standard practice. The faces, therefore, are no higher at the end of the season than when they are chipped once a week.

Double chipping, of course, entails extra expense, but this is much more than offset by increased returns. With all additional expenses taken into account, and in the light of present prices, double chipping ought to increase the net profits from a crop (10,000 faces) by about \$450. This means an increase in net profits from a 50-crop operation of about \$22,000.

While the experiments reported in this bulletin actually show a large increase in yields and revenue as a result of double chipping, it must be borne in mind that they cover only the first year's opera-

tion upon virgin timber, and that no data are as yet available showing what effect double chipping would have upon the yield in the second and subsequent years. It is the intention to pursue the investigations further so that data covering an entire operation may be secured.

The naval-stores industry can not expand at will. About 5,000,000 acres must be tapped each year to maintain the present production. In the same period lumbering removes the trees from about 1,000,000 acres of virgin longleaf and slash pine, so the available field of operation is growing steadily smaller. "More naval stores from the same tree" must be the watchword of the industry if it is to meet the probable demand for turpentine and rosin without crippling itself for the future.

#### PLAN OF THE EXPERIMENTS.

The chipping was done on the holdings of a lumber company at Columbia, Miss. Three experimental areas were devoted to standard, narrow, and double chipping, respectively.

##### STANDARD CHIPPING.

Crops Nos. 2 and 5, with a total of 6,153 cups, were chipped weekly with a No. 2 hack. The depth of the streak varied from one-half to three-fourths inch. In order that the chipping might conform as nearly as possible to that prevailing on the place, no supervision was exercised beyond recording the data.

##### NARROW CHIPPING.

The area selected for narrow chipping consisted of all of crop No. 4 and one drift of crop No. 3, with a total of 6,881 faces. Four standard streaks had already been made on this area before the experiments were started. During the remainder of the season a streak about one-fourth inch high and of the same depth as the standard was cut every week. This insured that, at the end of the season, the faces would be approximately one-half the height of the standard. At first a specially constructed hack with a  $\frac{3}{8}$ -inch bill opening was used, but later was abandoned because it broke too easily. After that the chipping was done with either a No. 00 or No. 1 hack.

##### DOUBLE CHIPPING.

Five drifts of crop No. 3, totaling 3,107 faces, were used for double chipping. This area also had received four standard streaks at the beginning of the season. The chipping was done in the same manner as the narrow chipping, except that two streaks were made per week, so that at the end of the season the faces would be of the same height as the standard faces. Chipping was done at intervals of three days. A drift chipped on Monday, for example, was chipped again on Thursday.



## COLLECTION OF DATA.

A careful record was kept of the net weight of all the crude gum collected on the experimental areas, with the exception of the first dipping which was made before the experiment could be started. A record was kept also for each area of the weight and grades of rosin produced and the number of gallons of turpentine as measured at the still. The still had a capacity of 10 barrels, but in order to maintain uniform conditions it was often necessary to hold over several barrels of gum until the next dipping before distilling.

The "scrape" from each plot was all collected at one time, but in distilling it 12 or 13 barrels formed the unit charge. What was left over was weighed as a basis for calculating the amount of turpentine and rosin represented by all the scrape, assuming the proportion of turpentine and rosin and the grade of rosin to be the same as in the case of the charge distilled. The same method of calculation was employed on a few barrels of "dip" remaining over at the end of the season. In this case the proportion of turpentine and rosin was assumed to be the same as that obtained from the last dipping. This dipping contained less turpentine than the average for the season, owing to the presence of considerable scrape cleaned from the faces and aprons.

At the beginning of the season, before the experiment proper had started, nine, nine, and four barrels of crude gum had been dipped from the standard, narrow, and double plots, respectively. No record was kept except as to the number of barrels, so an estimate was made of the weight of gum and the yield of rosin and turpentine based on the average weights and yields of the gum from the first few charges immediately following.

On the standard, and especially on the double-chipping areas, the gum from a considerable number of faces was lost during a large part of the season from causes ordinarily avoidable. The camp and still were located in the double-chipping area and near the standard area. Some of the trees were cut to make room for additional buildings, some were cut for structural timbers, while others had to be abandoned for various reasons. At the end of the season a careful count of these faces was made and the loss estimated according to the height of the face. Two faces that had been chipped for one-half the season were considered as one face lost for the entire season. The number of faces lost in this manner was subtracted from the original count in each plot, and the number thus obtained was taken as the actual number of faces upon which to base the yields.

A number of faces in each plot were not chipped a portion or all of the season for causes that might be met with in any operation. These included faces in out-of-the-way corners among undergrowth, and missed intentionally or otherwise by the chipper; those along

streams made inaccessible by débris from freshets; trees blown down or struck by lightning: those where cups had been hung on the dead side of the tree; and faces that "dried out" soon after chipping. A count was made of such faces, including every one that had dried out to any extent and those on trees that had died from unknown causes. The portions of the season lost by these faces are given in Table 1. The yields for the season have not been corrected for such losses, since these must be accepted in all operations.

TABLE 1.—*Faces lost on account of "dry peaks," "dry faces," trees dying, faces not being chipped, and various causes not avoidable in turpentine operations.*

| Plot.                  | Actual faces worked. | Portion of season lost— |                                  |                                  |                       | Portion of season lost by faces on trees dying for reasons not apparent— |                                  |                                  |                       |
|------------------------|----------------------|-------------------------|----------------------------------|----------------------------------|-----------------------|--------------------------------------------------------------------------|----------------------------------|----------------------------------|-----------------------|
|                        |                      | 0 to $\frac{1}{2}$ .    | $\frac{1}{2}$ to $\frac{3}{4}$ . | $\frac{3}{4}$ to $\frac{7}{8}$ . | $\frac{7}{8}$ to all. | 0 to $\frac{1}{2}$ .                                                     | $\frac{1}{2}$ to $\frac{3}{4}$ . | $\frac{3}{4}$ to $\frac{7}{8}$ . | $\frac{7}{8}$ to all. |
| Standard chipping..... | 6,142                | 151                     | 33                               | 17                               | 2                     | 2                                                                        | 20                               | 8                                | 2                     |
| Narrow chipping.....   | 6,881                | 149                     | 28                               | 16                               | 11                    | 3                                                                        | 5                                | 11                               | 0                     |
| Double chipping.....   | 3,049                | 90                      | 37                               | 16                               | 13                    | 2                                                                        | 4                                | 0                                | 3                     |

### YIELDS.

The actual yields obtained are given in Table 2. In this table, as well as throughout the bulletin, the weight of the rosin includes the weight of the barrel. Usually in selling rosin no deduction is made from the gross weight. Since each of the three areas had a different number of faces, in Table 3, for purposes of comparison, the figures are reduced to a basis of 10,000 faces, or one crop, which usually is taken as the standard unit in the naval-stores industry.

Little importance should be attached to the difference in the grades and in the amount of each grade of rosin produced by the different areas, since the grades were lowered by carrying over a few barrels of gum from one charge to the next, as explained. The deterioration on standing was shown by a simple experiment with gum from the standard area.

Sixteen barrels of this gum were held over for nearly a month during the middle of the season. At the time this gum was collected, that from the entire place produced rosin which graded about 60 per cent W G and N. The treatment of this gum in the woods and at the still was similar to that given the 16 barrels held over, except for the time elapsing between collection and distillation. All the rosin from these 16 barrels graded M at least one grade lower than that from the fresh gum. The total effect of the stored gum on the grades of rosin could not be determined, so that in considering the economic side of the experiments a nominal uniform price per barrel will be selected.



F-I-S. & P.

NARROW CHIPPED FACES ARE ONLY HALF AS HIGH AT THE END OF THE SEASON  
AS WHEN THE STREAKS ARE CUT ONE-HALF INCH.





F-3736M

DOUBLE CHIPPED FACES ARE NO HIGHER AT THE END OF THE SEASON THAN THOSE CHIPPED ONCE A WEEK.

The scrape was distilled the day following collection, but even in this case a comparison of the grades of rosin may be erroneous. At the time of distillation the price of turpentine was high, while the higher grades of rosin differed little in value, so that the quality of the rosin sometimes was sacrificed for a higher yield of turpentine.

TABLE 2.—Yield of crude gum, scrape, rosin, and turpentine from experimental plots.

| Plot.             | Number of cups. | Yield of gum. | Turpentine from gum. | Rosin from gum.                                                   |                                   | Yield of scrape. | Turpentine from scrape. | Rosin from scrape.                    |                  | Total rosin. | Total turpentine. |
|-------------------|-----------------|---------------|----------------------|-------------------------------------------------------------------|-----------------------------------|------------------|-------------------------|---------------------------------------|------------------|--------------|-------------------|
|                   |                 |               |                      | Lbs.                                                              | Grade.                            |                  |                         | Lbs.                                  | Grade.           |              |                   |
| Standard chipping | 6,142           | Lbs. 63,926   | Gal. 1,709.5         | Lbs. 19,624<br>6,882<br>12,941<br>2,480<br>8,770                  | WW<br>WG<br>M<br>K<br>I           | Lbs. 16,545      | Gal. 293                | Lbs. 3,633<br>7,164<br>3,328          | N<br>M<br>K      | Lbs. 64,822  | Gal. 2,002.5      |
| Total.....        |                 |               |                      | 50,697                                                            |                                   |                  |                         | 14,125                                |                  |              |                   |
| Narrow chipping.  | 6,881           | 61,062        | 1,618                | Lbs. 14,496<br>5,755<br>7,422<br>6,430<br>5,661<br>8,460          | WW<br>WG<br>N<br>M<br>K<br>I      | Lbs. 14,515      | 235                     | Lbs. 2,970<br>3,485<br>2,970<br>2,225 | N<br>M<br>K<br>H | 59,874       | 1,853             |
| Total.....        |                 |               |                      | 48,224                                                            |                                   |                  |                         | 11,650                                |                  |              |                   |
| Double chipping.. | 3,049           | 42,687        | 1,092                | Lbs. 10,652<br>2,860<br>3,600<br>3,405<br>2,550<br>3,668<br>5,439 | WW<br>WG<br>N<br>M<br>K<br>I<br>H | Lbs. 13,615      | 209                     | Lbs. 1,165<br>10,427                  | N<br>M           | 43,766       | 1,301             |
| Total.....        |                 |               |                      | 32,174                                                            |                                   |                  |                         | 11,592                                |                  |              |                   |

TABLE 3.—Yield of crude gum, scrape, rosin, and turpentine per crop of 10,000 faces on each of the experimental plots.

| Plot.               | Yield of gum. | Turpentine from gum. | Rosin from gum.                                                       |                                   | Yield of scrape. | Turpentine from scrape. | Rosin from scrape.                    |                  | Total rosin. | Total turpentine. |
|---------------------|---------------|----------------------|-----------------------------------------------------------------------|-----------------------------------|------------------|-------------------------|---------------------------------------|------------------|--------------|-------------------|
|                     |               |                      | Lbs.                                                                  | Grade.                            |                  |                         | Lbs.                                  | Grade.           |              |                   |
| Standard chipping.. | Lbs. 104,080  | Gal. 2,783           | Lbs. 31,951<br>11,205<br>21,070<br>4,037<br>14,279                    | WW<br>WG<br>M<br>K<br>I           | Lbs. 26,936      | Gal. 477                | Lbs. 5,915<br>11,664<br>5,418         | N<br>M<br>K      | Lbs. 105,539 | Gal. 3,260        |
| Total.....          |               |                      | 82,542                                                                |                                   |                  |                         | 22,997                                |                  |              |                   |
| Narrow chipping.... | 88,740        | 2,351                | Lbs. 21,067<br>8,364<br>10,785<br>9,345<br>8,227<br>12,294            | WW<br>WG<br>N<br>M<br>K<br>I      | Lbs. 21,094      | 342                     | Lbs. 4,316<br>5,065<br>4,316<br>3,234 | N<br>M<br>K<br>H | 87,014       | 2,693             |
| Total.....          |               |                      | 70,082                                                                |                                   |                  |                         | 16,931                                |                  |              |                   |
| Double chipping.... | 140,003       | 3,582                | Lbs. 34,936<br>9,380<br>11,807<br>11,168<br>8,363<br>12,030<br>17,839 | WW<br>WG<br>N<br>M<br>K<br>I<br>H | Lbs. 44,654      | 685                     | Lbs. 3,821<br>34,198                  | N<br>M           | 143,542      | 4,267             |
| Total.....          |               |                      | 105,523                                                               |                                   |                  |                         | 38,019                                |                  |              |                   |

In Table 4 the total quantities of turpentine and rosin obtained by narrow, double, and standard chipping are compared on a percentage basis. Double chipping increased the yields of turpentine and rosin 30.9 per cent and 36 per cent, respectively. The greater increase in rosin is due to the heavy yield of scrape. The yields of turpentine and rosin were decreased 17.4 per cent and 17.5 per cent, respectively, by narrow chipping. It will be noted, however, that the narrow faces are only about one-half the height of the standard or double faces. The comparative heights of the faces are shown in Plates I and II.

In Table 5 the yields have been arranged with respect to the height of face, the widths of all the faces being practically identical. On this basis the narrow chipping produced about 40 per cent more turpentine and rosin than the standard. Narrow chipping, however, would not be practical in the light of present prices for labor and timber leases.

TABLE 4.—*Comparison of the yields per crop by the various methods of chipping.*

| Plot.                  | Yield of<br>turpen-<br>tine. | Compared<br>with<br>standard. | Yield of<br>rosin. | Compared<br>with<br>standard. |
|------------------------|------------------------------|-------------------------------|--------------------|-------------------------------|
|                        | Gallons.                     | Per cent.                     | Pounds.            | Per cent.                     |
| Standard chipping..... | 3,260                        | 100                           | 105,539            | 100                           |
| Narrow chipping.....   | 2,693                        | 82.6                          | 87,014             | 82.5                          |
| Double chipping.....   | 4,267                        | 130.9                         | 143,542            | 136                           |

#### EFFECT OF DOUBLE CHIPPING ON THE TREES.

The effect that double chipping will have upon the timber during subsequent years of operation must be considered. The same trees will be tapped during the coming season, and until the additional data are available the advisability of using the method over a period of years must remain in doubt. Some data in regard to the severity of the several methods, however, will be found in Table 2. By far the greater number of faces recorded in this table, especially those that had lost from 0 to  $\frac{1}{4}$  the season, were "dry" faces. This condition has been the result of old or "doty" timber or the direct result of turpentinizing. In the standard chipping a total of 235 faces, or 38.3 per thousand, were affected. The narrow chipping contained 223 injured faces, or 32.4 per thousand, while the double chipping contained 165, or 54 per thousand.

This would seem to indicate that double chipping is the severest and narrow chipping the least so. However, in the second part of Table 1, it will be noted that in the standard chipping there were 32 faces on trees that had died for no apparent reasons, equivalent to 5.2 faces per thousand. For the narrow and double chipping the



figures are 2.8 and 2.9 per thousand, respectively. These trees may have died from tapping or from natural causes. If the dead faces were the result of turpentinizing, it would indicate that standard chipping was hardest on the timber, the double next, and the narrow easiest. It is logical to assume, however, that double chipping would be severer than the standard. Since most of the trees died early in the season, it is probable that method of chipping had little effect.

TABLE 5.—*Comparative yields per crop with respect to height of face.*

| Plot.                     | Height of face. | Number of streaks. | Average height of streak. | Turpentine.     |                     |                  | Rosin.         |                     |                  |
|---------------------------|-----------------|--------------------|---------------------------|-----------------|---------------------|------------------|----------------|---------------------|------------------|
|                           |                 |                    |                           | Total yield.    | Per inch of height. | Increase.        | Total yield.   | Per inch of height. | Increase.        |
|                           | <i>Inches.</i>  |                    | <i>Inches.</i>            | <i>Gallons.</i> | <i>Gallons.</i>     | <i>Per cent.</i> | <i>Pounds.</i> | <i>Pounds.</i>      | <i>Per cent.</i> |
| Standard.....             | 21.95           | 38                 | 0.58                      | 3,260           | 148                 | .....            | 105,539        | 4,808               | .....            |
| Narrow <sup>1</sup> ..... | 12.85           | 38                 | .34                       | 2,693           | 209                 | 41.2             | 87,014         | 6,771               | 40.8             |
| Double <sup>1</sup> ..... | 23.67           | 70                 | .34                       | 4,267           | 180                 | 21.6             | 143,542        | 6,064               | 23.1             |

<sup>1</sup> The narrow and double areas had four standard streaks before the experiment started. The height of the four streaks averaged 2.75 inches from 25 measurements. With this allowance, the streaks on the narrow and double areas averaged 0.30 and 0.32 inch, respectively. The corrected height for the double face is 22.20 inches and for the narrow face 11.38 inches.

#### PRACTICABILITY OF DOUBLE CHIPPING.

In the experiments the double chipping was done on exact schedule. Certain trees were chipped always on prescribed days of the week, except in a few instances when weather interfered. It is very improbable that an exact schedule could be maintained on a 50-crop place, but for practical purposes this would not be necessary. In the experiment the number of faces for double chipping was made small enough for the chipper to cover the ground easily on scheduled time. In practice each chipper would have about 4,000 faces. Since few chippers can handle more than this number in three days, it is improbable that the second streak would be applied too soon. It is expected that a streak would be missed occasionally, as this frequently happens with the present method of chipping. The idea is not to have a rigid schedule impossible to follow, but so far as possible to make two streaks per week where the old method requires one, these two streaks not to increase the height of the face more than the one standard streak. In every case, however, at least three days should elapse between streaks.

The chief problem would be to find a sufficient number of chippers. The smaller streak is not difficult to cut. More care is required in making it, but less effort is required to drive the hack through the wood. Standard No. 0 or No. 00 hacks were found to give the best results.

TABLE 6.—*Monthly rainfall and temperature during the season of 1916 at Columbia, Miss.*

| Rainfall and temperature.                                             | March. | April. | May.   | June.  | July.  | August. | September. | October. |
|-----------------------------------------------------------------------|--------|--------|--------|--------|--------|---------|------------|----------|
| Mean rainfall at Columbia.....inches..                                | 5.20   | 3.83   | 12.44  | 1.64   | 9.25   | 2.54    | 2.28       | 2.33     |
| Departure from normal at Columbia.....inches..                        | — .19  | — 2.24 | + 5.65 | — 3.21 | + 3.12 | — 1.63  | — 3.48     | — .17    |
| Mean temperature for Columbia...°F..                                  | 60.2   | 64.8   | 75.3   | 80.2   | 82.6   | 82.5    | 75.6       | 65.4     |
| Mean temperature for the State for a period of over 10 years.....°F.. | 57.8   | 64.3   | 71.9   | 78.7   | 80.9   | 80.8    | 75.9       | 64.0     |

The above data show that the season can not be considered as unusual in regard to either rainfall or temperature.

#### RETURNS FROM DOUBLE CHIPPING IN DOLLARS AND CENTS.

During the season of 1916 the price of turpentine varied from 36 to 50 cents per gallon, Savannah quotations. During the greater portion of the season turpentine was quoted at more than 40 cents, but at the still it sold at Savannah quotations, less freight rates to this market. For the purposes of this report, 40 cents per gallon will be taken as the average price of turpentine for 1916.

Very little difference in price existed between the various grades of rosin during the season of 1916. Water-white and window-glass rosins were produced almost exclusively up to August 1, the prices ranging from \$5.10 to \$6.60 for WG and \$5.20 to \$6.90 for WW. After August 1, F, the lowest grade of rosin produced on the place, sold at from \$6 to \$6.35. In order to make a conservative estimate of the added returns, the average price of rosin at the still was assumed to be \$5 per barrel.

Upon this basis the increased yield from double chipping would show the following excess value per crop:

|                                                                       |          |
|-----------------------------------------------------------------------|----------|
| 1,007 gallons increase in turpentine, at 40 cents per gallon.....     | \$402.80 |
| 38,003 pounds increase in rosin, at \$5 per barrel of 280 pounds..... | 678.50   |
| Total.....                                                            | 1,081.30 |

From this amount should be subtracted the extra cost of operating under the new method. Besides the actual cost of the extra streaks, other expenses are entailed. On a 50-crop place it will be necessary to maintain from 55 to 60 extra men, requiring about 35 extra houses at \$150 each. Against the houses must be charged interest on the investment and a depreciation of about 30 per cent. There would also be needed an extra woodman at \$900 per year, and an extra "stiller" with a crew of four, requiring an expenditure of about \$2,000 per year. Numerous additional minor expenses will be found listed in Table 7, in which the extra charges have been reduced to the one-crop basis.

These figures show that double chipping will increase the net profits per crop by about \$450.

|                                     |            |
|-------------------------------------|------------|
| Increase from additional yield..... | \$1,081.30 |
| Extra cost of using new method..... | 631.60     |

|               |        |
|---------------|--------|
| Net gain..... | 449.70 |
|---------------|--------|

At present prices the total net gain from a 50-crop place would be about \$22,000.

Many of the large lumber companies tap their timber from two to three years before cutting. Frequently turpentinizing is barely a year ahead of cutting. It is in these cases that double chipping should be especially advantageous.

TABLE 7.—*Added cost per crop of double chipping as conducted on the experimental area.*

| Item.                                                    | Number on double. | Number on single. | Price.              | Cost per crop on double. | Cost per crop on standard. | Extra cost per crop on double. |
|----------------------------------------------------------|-------------------|-------------------|---------------------|--------------------------|----------------------------|--------------------------------|
| Chipping.....streaks..                                   | 70                | 38                | <sup>1</sup> \$9.00 | \$630.00                 | \$342.00                   | \$288.00                       |
| Dipping.....barrels..                                    | 334               | 248               | 2.48                | 133.60                   | 99.20                      | 34.40                          |
| Hauling gum.....do..                                     | 334               | 248               | 2.50                | 167.00                   | 124.00                     | 43.00                          |
| Scraping.....do..                                        | 149               | 90                | 2.40                | 59.60                    | 36.00                      | 23.60                          |
| Hauling scrape.....do..                                  | 149               | 90                | 2.50                | 74.50                    | 45.00                      | 29.50                          |
| Rosin.....do..                                           | 298               | 220               | 2.75                | 223.50                   | 165.00                     | 58.50                          |
| Interest and depreciation on extra houses, per crop..... |                   |                   |                     |                          |                            | 28.60                          |
| Extra help at still.....per year..                       |                   |                   | 110.00              |                          |                            | 40.00                          |
| Cost of extra woodsman.....do..                          |                   |                   | 2,000.00            |                          |                            | 18.00                          |
| 4 extra hacks.....                                       |                   |                   | 900.00              |                          |                            | 3.00                           |
| 4 extra dip barrels.....per crop..                       |                   |                   | .75                 |                          |                            | 10.00                          |
| Recruiting.....                                          |                   |                   | 2.50                |                          |                            | 5.00                           |
| Miscellaneous extras such as marketing, etc.             |                   |                   |                     | 25.00                    | 20.00                      | 50.00                          |
| Total.....                                               |                   |                   |                     |                          |                            | 631.60                         |

<sup>1</sup> Per streak.

<sup>2</sup> Per barrel.

### SUMMARY.

1. Double chipping produced, in the first year's operation, 31 per cent more turpentine and 36 per cent more rosin than standard chipping. The height of the face at the end of the season was approximately the same as that of the standard face.

2. The net gain from double chipping was about \$450 per crop.

3. Narrow chipping produced 17.5 per cent less turpentine and rosin than standard chipping; the faces were only one-half as high as the standard at the end of the season.

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# UNITED STATES DEPARTMENT OF AGRICULTURE



## BULLETIN No. 568

Joint Contribution from the Bureau of Plant Industry  
WM. A. TAYLOR, Chief, and the Bureau of  
Chemistry, CARL L. ALSBERG, Chief



Washington, D. C.

PROFESSIONAL PAPER

August 8, 1917

### THE PRESENCE OF ARSENIC IN HOPS.

By W. W. STOCKBERGER, *Physiologist in Charge of Drug-Plant and Poisonous-Plant Investigations, Bureau of Plant Industry*, and W. D. COLLINS, *Food-Investigation Chemist, Bureau of Chemistry*.

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#### SITUATION WITH RESPECT TO ARSENIC IN HOPS.

At times the detection of minute traces of arsenic in shipments of American hops exported to foreign countries has led to their rejection by prospective purchasers. The loss sustained in such cases is borne by the exporter; consequently American growers, who sell as a rule to local buyers only, do not realize fully the extent to which the salability of American hops on foreign markets may be affected unfavorably by an occasional contaminated shipment.

The profitableness of hop production in the United States is determined practically by the extent of the foreign demand for the crop surplus in excess of the requirements for domestic consumption. Any impairment of the quality of American hops, whether definitely proved or only suspected by foreign consumers, lessens the chances for marketing the surplus at reasonable prices and eventually reacts upon the grower in a lower price for his product. Although the probability of any damage to the public health from arsenic communicated by hops to ale or beer seems very remote, nevertheless the minute quantity of arsenic permissible in hops under some foreign standards of purity lays the grower under obligation to use every reasonable precaution to avoid all possible sources of contamination.

In a bulletin published in 1908 by the Bureau of Plant Industry,<sup>1</sup> impure sulphur was suggested as the source of the traces of arsenic

<sup>1</sup> Stockberger, W. W. The sources of arsenic in certain samples of dried hops. *In* U. S. Dept. Agr., Bur. Plant Indus. Bul. 121, p. 41-46. 1908.

occasionally found in American hops, and hop growers and handlers were urged to avoid the use of sulphur which could contaminate the hops in the process of drying and curing. Following this publication some hop growers made an effort to secure arsenic-free sulphur, but most of the growers on the Pacific coast continued to use impure sulphur, with the result that each year hops contaminated with arsenic have found their way into foreign markets. In the hops produced in the crop year 1914 the quantity of arsenic present was in many cases so much larger than usual that some English consumers brought the matter informally to the attention of the Bureau of Plant Industry and expressed the hope that American hop growers could be made to realize the seriousness of the situation from the standpoint of the foreign purchaser.

From an inquiry made among the hop growers of the Pacific coast it appeared that the sulphur in common use for bleaching hops was generally regarded either as free from arsenic or as containing this element in quantities so small that no injury would result from its use. The soil, commercial fertilizers, and materials used in spraying, rather than the sulphur, were all suggested as probable sources of the arsenic in hops, but on account of the prevailing uncertainty as to its real source little progress apparently was made in the production of hops of a quality more acceptable to the foreign trade. The reliability of the methods used for the determination of small quantities of arsenic in hops and similar materials was questioned by some who had given careful consideration to the subject. Therefore, the Bureau of Plant Industry and the Bureau of Chemistry undertook a joint investigation in order to establish definitely the source of the contamination of the hops. The field investigation and the collection of samples were made by the representative of the Bureau of Plant Industry, while the study of methods of analysis and the analyses of the samples collected were made in the Bureau of Chemistry.

#### COLLECTION OF MATERIALS FOR EXAMINATION.

The hop-producing sections of Oregon were visited during the hop harvest of 1915, and a carefully selected series of samples of both hops and sulphur was obtained. Definite information was in hand regarding the origin of certain bales of hops of the crop of 1914 which had been rejected by English purchasers, and it was therefore possible to locate the particular fields on which the hops in many of these bales were produced. It was possible also in some cases to locate and examine the kilns in which some of the rejected hops were dried and to secure samples of the sulphur used in their preparation.

Composite samples of hops from several fields were secured by taking a few hops from each of a number of vines in a field. These



samples were collected just before the crop was picked and were dried carefully in the open air, thus avoiding any possible chance of contamination from the sulphur. For comparison with the field samples thus prepared, samples of the hops from these fields, as well as samples of the sulphur used to bleach them, were taken at the kilns. Samples of kiln-dried hops and, when possible, samples of the sulphur used in bleaching them, were also secured from several widely separated localities. The soils on which these hops were produced varied from the alluvial sandy loam along the river to the clay loam of the uplands and represented practically all the soil types ordinarily used for the production of hops.

Some samples of Fuggle, an early variety, also were collected for comparison as to arsenic content with the later variety known as Cluster or English Cluster.

### ANALYSIS OF MATERIALS.

Arsenic was determined by the modified Gutzeit method, following in general the procedure outlined by C. R. Smith.<sup>1</sup> A discussion of the method and of the reasons for adopting the exact details followed in this work will be published elsewhere.<sup>2</sup> The hops were treated with nitric and sulphuric acids to destroy organic matter. The sulphur was treated with bromin<sup>3</sup> and the arsenic separated from the sulphur bromid by extraction with bromin water. In all cases arsenic was precipitated as ammonium magnesium arsenate by adding microcosmic salt, magnesia mixture, and ammonia. The precipitate of phosphate and arsenate was dissolved in sulphuric or hydrochloric acid, the arsenic reduced by stannous chlorid, and arsin generated by the use of zinc. The arsin was allowed to pass over a strip of paper containing mercuric bromid, making a brown stain, the length of which depended upon the quantity of arsenic in the sample. When large quantities of arsenic were present the arsin was passed into a solution of mercuric chlorid; the precipitated mercurous chlorid was filtered on ignited asbestos in a Gooch crucible, dried, and weighed.

### RESULTS OF ANALYSES.

The results of the analyses of the field samples, dried in the sun without contact with sulphur fumes, are given in Table I. Although these samples came from widely separated yards and represented two varieties of hops, little difference is shown in their arsenic content, which is uniformly small. The analysis of samples 176, 201, and 202,

<sup>1</sup> Smith, C. R. The determination of arsenic. U. S. Dept. Agr., Bur. Chem. Cir. 102, 12 p., 2 fig. 1912.

<sup>2</sup> Collins, W. D. C. R. Smith's method for the determination of arsenic (with special reference to the determination of arsenic in hops and in sulphur). Presented at the meeting of the Assoc. Off. Agr. Chem., Nov. 20-22, 1916. (To be published in Jour. Assoc. Off. Agr. Chem.)

<sup>3</sup> Smith, W. Estimation of selenium in sulfur. In Jour. Indust. and Engin. Chem., v. 7, no. 10, p. 849-850. 1915.

which were of the Fuggle variety, do not differ essentially from those of the remaining samples, which were of the English Cluster variety.

Samples 178 and 186, taken from yards which were not sprayed, showed practically the same quantity of arsenic as the samples from yards sprayed with a solution of whale-oil soap and quassia.

The quantities of arsenic found in the unsulphured samples were far below the limit of 0.01 grain per pound (1.4 parts per million) set in England by the Royal Commission on Arsenical Poisoning.

TABLE I.—*Arsenic in sun-dried unsulphured hops grown at Independence, Oreg., in 1915.*

| No. | Source of sample. | Arsenic as $As_2O_3$<br>(part per million). | No. | Source of sample. | Arsenic as $As_2O_3$<br>(part per million). |
|-----|-------------------|---------------------------------------------|-----|-------------------|---------------------------------------------|
| 176 | Yard A.....       | 0.2                                         | 196 | Yard G.....       | 0.2                                         |
| 177 | do.....           | .2                                          | 199 | Yard H.....       | .2                                          |
| 178 | Yard B.....       | .2                                          | 201 | Yard I.....       | .1                                          |
| 183 | Yard C.....       | .1                                          | 202 | do.....           | .1                                          |
| 186 | Yard D.....       | .1                                          |     |                   |                                             |
| 187 | Yard E.....       | .1                                          |     | Average.....      | .16                                         |
| 194 | Yard F.....       | .3                                          |     |                   |                                             |

The quantities of arsenic found in samples of sulphured hops are given in Table II. Where possible, samples of the sulphur used in curing these hops were collected and analyzed. The results of these analyses also are given in Table II.

Of the 26 samples of kiln-dried hops only four, of which two were duplicates, contained less than 1 part of arsenic per million parts of hops. The average results show that whereas unsulphured hops contain no appreciable quantity of arsenic, hops which were treated with fumes from sulphur having about 100 parts of arsenic ( $As_2O_3$ ) per million contained about 3 or 4 parts of arsenic per million parts of hops.

On account of the irregularity of distribution of arsenic in the sulphur, it is not possible to be sure that any sample of hops was treated with sulphur of exactly the composition of the sample taken to represent the sulphur. The quantity of sulphur used is also variable, ranging from 1 to 4 pounds of sulphur for 25 pounds of dried hops. Notwithstanding all these chances for disagreement, the results in Table II show in general a relation between the quantities of arsenic in the hops and in the sulphur used in curing. The quantities of arsenic in the hops average about 3 or 4 per cent of the quantity in the sulphur used in curing. On this basis sulphur containing 25 or 30 parts of arsenic per million would on the average contaminate hops with about 1 part of arsenic per million parts of hops. If the arsenic is unevenly distributed through the sulphur it is possible that some samples of hops might contain much more arsenic than the quantity which would correspond to the arsenic in the sulphur.

TABLE II.—*Arsenic in kiln-dried hops and in sulphur used in curing certain lots of hops grown in Oregon in 1915.*

| No. | Source of sample. |               | Arsenic as $\text{As}_2\text{O}_3$ (parts per million). |                 | No.       | Source of sample. |            | Arsenic as $\text{As}_2\text{O}_3$ (parts per million). |                 |
|-----|-------------------|---------------|---------------------------------------------------------|-----------------|-----------|-------------------|------------|---------------------------------------------------------|-----------------|
|     | Place.            | Yard, etc.    | In the hops.                                            | In the sulphur. |           | Place.            | Yard, etc. | In the hops.                                            | In the sulphur. |
| 195 | Independence.     | Yard G.       | 0.4                                                     | 20              | 208       | Brooks.           | Yard B.    | 0.5                                                     | 4.4             |
| 229 | do.               | Yard G dupli. | 6.6                                                     | 20              | 205       | Springfield.      | Yard A.    | 4.2                                                     |                 |
| 233 | do.               | Yard G cates. | 7.1                                                     | 210             | do.       | Yard B.           | 4.1        |                                                         |                 |
| 198 | do.               | Yard H.       | 5.2                                                     | 116             | 206       | Harrisburg.       | Yard A.    | 2.6                                                     |                 |
| 180 | do.               | Yard K.       | 3.8                                                     | 356             | 209       | do.               | Yard B.    | 4.5                                                     |                 |
| 207 | do.               | Yard L.       | 1.0                                                     | 211             | do.       | Yard C.           | 26.0       |                                                         |                 |
| 224 | do.               | Yard M.       | 6.1                                                     | 35              | 212       | Aurora.           | 3.4        | 115                                                     |                 |
| 228 | do.               | Yard N dupli. | 1.3                                                     | 214             | Donald.   | Yard A.           | 2.7        | 90                                                      |                 |
| 322 | do.               | Yard N cates. | 1.2                                                     | 216             | do.       | Yard B.           | 3.4        | 123                                                     |                 |
| 230 | do.               | Yard O dupli. | 1.9                                                     | 218             | St. Paul. | Yard B.           | 3.8        | 116                                                     |                 |
| 234 | do.               | Yard O cates. | 1.9                                                     | 223             | Suver.    |                   | 3.9        | 76                                                      |                 |
| 231 | do.               | Yard P dupli. | .2                                                      | 225             | Banks.    |                   | 4.2        | 188                                                     |                 |
| 235 | do.               | Yard P cates. | .2                                                      |                 |           |                   |            |                                                         |                 |
| 204 | Brooks.           | Yard A.       | 1.9                                                     |                 |           | Average.          |            | 3.93                                                    |                 |

Analyses of all the samples of sulphur collected are given in Table III. With a few exceptions these samples were taken from the hop yards and are representative of the sulphur used in curing the crop of 1915. Three samples of sulphur used in curing the crop of 1914 and two commercial samples also are included.

The quantity of sulphur on hand at the hop kilns varied from a few hundred pounds to several tons. As a rule, the individual lots were far from uniform in appearance, and in many cases several different kinds of sulphur seemed to be present. Some pieces were of a bright lemon-yellow color and others of various shades of orange. Some pieces were hard and glasslike; others appeared more crystalline and crumbled readily, while some pieces were porous, resembling pumice in appearance. In most of the lots the sulphur consisted of pieces of different sizes, from lumps 6 or 8 inches across down to a fine powder. This made sampling difficult, but the agreement between the values obtained for samples 181 and 200, which were taken to represent the sulphur in one lot, indicates that the samples were representative of the various lots at the time of sampling.

TABLE III.—*Arsenic in sulphur used for curing hops grown in Oregon in 1915.*

| No. | Source of sample. |                      | Arsenic as $\text{As}_2\text{O}_3$ (parts per million). | No. | Source of sample. |                    | Arsenic as $\text{As}_2\text{O}_3$ (parts per million). |
|-----|-------------------|----------------------|---------------------------------------------------------|-----|-------------------|--------------------|---------------------------------------------------------|
|     | Place.            | Yard, etc.           |                                                         |     | Place.            | Yard, etc.         |                                                         |
| 182 | Independence.     | Yard B.              | 64                                                      | 213 | Aurora.           |                    | 115                                                     |
| 191 | do.               | Yard F (1915)        | 197                                                     | 215 | Donald.           | Yard A.            | 90                                                      |
| 192 | do.               | Yard F (1914)        | 170                                                     | 217 | do.               | Yard B.            | 123                                                     |
| 197 | do.               | Yard H.              | 116                                                     | 219 | St. Paul.         |                    | 116                                                     |
| 179 | do.               | Yard K (1915)        | 66                                                      | 220 | Brooks.           | Yard B.            | 4.4                                                     |
| 181 | do.               | Yard K (1914) dupli. | 356                                                     | 222 | Suver.            |                    | 76                                                      |
| 200 | do.               | Yard K (1914) cates. | 329                                                     | 226 | Banks.            |                    | 188                                                     |
| 221 | do.               | Yard M.              | 35                                                      | 190 | Independence.     | Commercial sample. | 3.6                                                     |
| 193 | do.               | Yard O.              | 20                                                      | 227 | Portland.         | Dealer's sample.   | 7.1                                                     |
| 189 | do.               | Yard R.              | 141                                                     |     | Average.          |                    | 116.7                                                   |



From two samples of sulphur several pieces of different appearance were picked out, ground, and analyzed for arsenic, with the results given in Table IV.

TABLE IV.—*Arsenic in different pieces of sulphur from the same field sample.*

| No. | Sub-sample. | Appearance.                        | Arsenic as $As_2O_3$ (parts per million). | No. | Sub-sample. | Appearance.                            | Arsenic as $As_2O_3$ (parts per million). |
|-----|-------------|------------------------------------|-------------------------------------------|-----|-------------|----------------------------------------|-------------------------------------------|
| 179 | 1           | Greenish yellow.....               | 10                                        | 183 | 3           | Lemon yellow, largely crystalline..... | 160                                       |
| 179 | 2           | Slightly orange, porous..          | 270                                       | 188 | 4           | Orange, vitreous.....                  | 150                                       |
| 179 | 3           | More orange than sub-sample 2..... | 160                                       | 188 | 5           | Lemon yellow, crystalline.....         | 50                                        |
| 179 | 4           | Average of the sample...           | 66                                        | 188 | 6           | Orange, vitreous.....                  | 450                                       |
| 188 | 1           | Average color.....                 | 35                                        | 188 | 7           | .....do.....                           | 300                                       |
| 188 | 2           | .....do.....                       | 80                                        |     |             |                                        |                                           |

After a small part of sample 179 had been removed in subsamples 1, 2, and 3, the remainder was ground and used as an average sample of 179 in the same way in which the other samples of sulphur were used. It is believed that the average value of 66 parts per million is not appreciably different from that which would be obtained for the arsenic in sample 179 if no subsamples had been removed. So many subsamples of sample 188 were taken that it was not possible to obtain an average value of this sample.

The results of analyses of the subsamples of sample 179 indicate that with sulphur taken from a lot containing on the average 66 parts of arsenic per million, one kiln of hops might be treated with fumes from sulphur containing 270 parts of arsenic per million, while the next treatment might be with sulphur containing only 10 parts of arsenic per million.

Since only a small quantity of sulphur is burned at one time in curing hops, it is very probable that the sulphur used on a particular kiln of hops will not contain the same quantity of arsenic as an average sample of the sulphur on hand.

The results for the subsamples of sample 188 show irregularity of distribution of arsenic much like that in sample 179. The relation between the arsenic in sulphur and in the hops for which the sulphur is used can not be very definite. No uniform quantity of sulphur is used for a given quantity of hops; the arsenic is not uniformly distributed through the hops in the kiln at one time and the arsenic is not uniformly distributed through the sulphur.

The analyses of samples 190, 220, and 227 show that sulphur can be obtained which is practically free from arsenic. The analyses of samples of hops cured with sulphur containing very little arsenic indicate that hops may be cured with sulphur containing as much as 10 parts of arsenic per million without becoming contaminated with more than 0.5 part of arsenic per million parts of hops.

## CONCLUSIONS.

The work here reported shows that sun-dried hops collected from various yards in Oregon in 1915 contained practically no arsenic.

The spraying materials in general use, such as solutions of whale-oil soap and quassia or nicotin sulphate are not to be held responsible for the contamination of hops with arsenic.

The sulphur in use in 1914 and 1915 was generally contaminated with arsenic, many samples containing over 100 parts of arsenic as  $\text{As}_2\text{O}_3$  in 1,000,000 parts of sulphur. When such sulphur is used in curing hops, the hops may contain three or four parts of arsenic per million parts of hops.

Little, if any, doubt remains that impure sulphur alone is responsible for the contamination of hops with appreciable quantities of arsenic.

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# UNITED STATES DEPARTMENT OF AGRICULTURE



## BULLETIN No. 569



Contribution from the Bureau of Chemistry  
CARL L. ALSBERG, Chief

Washington, D. C.



June 25, 1917

### THE SANITARY CONTROL OF TOMATO-CANNING FACTORIES.

By BURTON J. HOWARD, *Microscopist in Charge, in collaboration with* CHARLES H. STEPHENSON, *Scientific Assistant, Microchemical Laboratory.*

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#### INTRODUCTION.

Marked changes in machinery and methods for the manufacture of food products have been made in the last 6 or 8 years under the stimulus of Federal and State pure food and sanitary laws. The manufacturer has come to appreciate the need for more sanitary methods. Certain individuals, firms, and corporations, of their own initiative, have blazed a path out of questionable or unsanitary surroundings in advance of Federal or State laws imposing such reforms. Much credit is due manufacturers of this type who are willing to improve their methods of manufacture regardless of the existence or nonexistence of laws making such improvements imperative. At the other extreme is that small class of manufacturers who are indifferent to the character of their product, either from the standpoint

of sanitation or from that of quality, as long as their product can be disposed of at a financial profit.

Between these two extreme types of manufacturers, one of which is alert and active in seeking constantly to improve conditions, and the other of which is devoid of care or interest in the business beyond the financial profit obtainable, there is a third and much larger class. This class comprises those men who are willing to make improvements in keeping with sound, sanitary practice, but whose experience, because of the purely commercial aspects of their business, has given them no opportunity personally to study the sanitary problems of their factories and to apply the information gained in a practical manner. In other words, many manufacturers are deterred from making improvements because of lack of knowledge either of the fundamental reasons for such improvements or of how to proceed.

The willingness of this class of manufacturers to make improvements, however, has rendered possible the great changes that have taken place in recent years in mechanical contrivances for cleaning and handling the various products used in the manufacture of foods. This progress is especially well illustrated in the tomato industry. For example, only a few years ago the sorting of tomatoes in the manufacture of ketchup and pulp was very uncommon, while to-day very few manufacturers do not at least profess to observe this step, however ineffectively the process sometimes may be performed. Various forms of tables and machines have been devised to assist in this important step of manufacture. Many forms of tomato-washing machines found in common use 6 or 7 years ago have become so obsolete that they are being consigned rapidly to the scrap heap as inadequate to meet present-day requirements. Processes, such as the "gravity system" of draining off the watery juice from pulp which was so very largely practiced less than 10 years ago, have been discarded by firms that are trying to keep abreast of their fellow manufacturers in matters of sanitation and quality. The custom of storing in barrels—general a few years ago—has now practically disappeared, except for the poorest grades of products. The barrel has been replaced by the 5 or 6 gallon tin can. The writer recalls having seen at one plant thousands of barrels in one lot being offered for sale because the firm had no further use for them, as it had adopted the more satisfactory system of storing its product in cans.

The manufacture of sanitary food products is too broad a problem to be covered in one publication. In the present bulletin the discussion will be limited to those conditions which apply particularly to tomato-canning factories. It is proposed to discuss some of the more important points concerning sanitary control of plants of this kind in a rather elementary manner and to avoid technicalities as far as possible.

### CONDITIONS OBSERVED IN SEVERAL TOMATO-CANNING FACTORIES.

Criteria of cleanliness are involved in the question of what constitutes a sanitary plant or product. Under the Food and Drugs Act, June 30, 1906, the Federal Government has no power to enforce sanitary rules except as it may prohibit the entrance into interstate commerce of products which are filthy, decomposed, or putrid.<sup>1</sup> Direct control over the factories themselves is wholly within the jurisdiction of the several States; the Federal Government can serve only in an advisory capacity. Various States have sanitary regulations, but in formulating them general terms must be used. Hence, in applying these regulations to specific cases considerable difference of opinion may appear because of the variation in training or experience of those making the inspection. It is easier to direct that "products shall be made in a sanitary manner" than to explain in concrete terms what is meant by these words. Therefore, it seems appropriate to tell of the conditions found in a few factories and what was done to correct them. These examples are cited not because they represent the average condition of tomato-canning factories throughout the country but because they illustrate conditions in a rather large class of establishments where the superintendents are sincere in considering their plants satisfactory when, as a matter of fact, their factories may be seriously deficient in some particulars.

At hearings held in connection with the enforcement of the Federal Food and Drugs Act it has occurred repeatedly that the manufacturers concerned have claimed that their products were made under absolutely sanitary conditions. Obviously, it is rarely possible to verify such statements by inspection, principally because the season when the goods were packed has already passed and the factory is more or less dismantled. Usually it is of little value to visit a plant in the out-of-season periods of the year if a study of sanitation under working conditions is desired. Such claims on the part of the manufacturers usually may be considered as candid and honest expressions of opinion, but field work has shown that lack of experience in matters of sanitation may produce very erroneous conclusions.

#### Factory No. 1.

About the middle of a recent tomato-packing season the following letter from a manufacturer of tomato products was received by the Bureau of Chemistry:

We wish to call your personal attention to a condition that is existing in the tomato-ketchup business as regards our own plant and, as we believe, the same condition exists in many other plants.

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<sup>1</sup> For the views of various Federal courts upon what constitutes a filthy, decomposed, or putrid product see Notices of Judgment 544, 649, 825, 873, 1693, 3372, 3400, and 4036; also National Canners Asso. Bul. 38, Jan. 20, 1917, Washington, D. C.



We are getting from the farmer a high-grade tomato, one that is perfectly sound and ripe. We are trimming our tomatoes very carefully and washing them in three different waters.

Reports from our chemist \* \* \* showed our earlier run to be:

| Mold.                      | Yeast and spores.  | Bacteria.          |
|----------------------------|--------------------|--------------------|
| In 7 per cent of fields... | 6 in 1/60 cmm..... | 10,500,000 per cc. |
| In 9 per cent of fields... | 7 in 1/60 cmm..... | 9,500,000 per cc.  |

Since then it has been gradually increasing until our last report shows the following:

|                           |                     |                    |
|---------------------------|---------------------|--------------------|
| 52 per cent of fields.... | 28 in 1/60 cmm..... | 21,000,000 per cc. |
| 44 per cent of fields.... | 28 in 1/60 cmm..... | 24,000,000 per cc. |

It is absolutely impossible for any human being and under any conditions to take tomatoes and manufacture a ketchup any more cleanly, any freer from mold or bacteria than the ketchup we are producing. There isn't a ketchup factory in the United States more cleanly or sanitary than ours. We are satisfied that this mold, yeast and spores, and bacteria is in the tomato in its healthy condition, that is, in perfectly sound tomatoes.

We know no one would condemn these tomatoes as being unfit for food. We are endeavoring to comply with the food law standard that has been established on tomato ketchup, but we can not go out of business simply because these standards have been made without due knowledge of the real chemical analysis of a perfectly sound, fresh tomato under all conditions, and when the raw product brought from the farmers is delivered to our plant and handled in a perfectly sound, clean, wholesome condition, we can not understand why our goods, which are strictly high-grade and pure, should be condemned by the Department of Agriculture under conditions of this kind.

We will very much appreciate if you will wire us just what to do. Also that you would have one of your representatives at our plant as quickly as he can get here, as we feel that we are entitled to the services of one of your personal representatives, as we know that our goods are right.

We know that they can not be manufactured under any more cleanly conditions than we are carrying out. We are therefore willing and entitled to make a stand on this, believing that the Agriculture Department will recognize the condition and protect us against any results that might come from our goods being picked up by food inspectors among our customers after they have left our warehouse.

Thanking you, and trusting that you will give this your immediate attention, we are,

Yours very truly,

The appeal in the letter enlisted the interest of the bureau and produced a desire for a careful investigation of the conditions complained of. Accordingly, the senior writer made a visit to the plant. It was the only factory in a small country town of about 100 inhabitants. Most of the employees, both men and women, came from the surrounding rural district. A stay of several days was made at the plant and various tests were conducted.

Examination of the sorted tomato stock showed that although at times it was not above criticism, poor sorting probably was not the main source of the trouble. The irregularity of sorting might have been due in part to the poor lighting of the sorting table. Observation of the method of cleaning the equipment at the end of the day's run, however, showed that the various parts of the washers, conveyors, cyclones, and pulp tanks were being only superficially cleaned. By reason of the method of construction or of the inaccessible location of the general equipment, some of its parts contained accumulations of tomato material fairly teeming with microorganisms.

Three cyclones were in use in this factory. The pulp tanks of two of these cyclones were connected with that of the third by means of wooden pipes. Examination of the inside of these pipes showed a thick growth which was so heavy in molds as to give a count of 100 per cent of the fields even after diluting 18 times. It was swarming with bacteria and yeasts and had an offensive, fetid odor. A count of bacteria gave over a billion per cubic centimeter. In other parts of the equipment the bacterial count went to a billion and a half and nematode worms were found in numbers as high as 1,080 per cubic centimeter. Yeasts and spores were present in numbers up to 4,000 per 1/60 cubic millimeter.<sup>1</sup> Examination under the microscope of a portion of the slimy coating showed it to be largely a mold growth with a mass of tomato debris and quantities of bacteria. Plate I shows photomicrographs of the mold. A specimen of it was identified<sup>2</sup> as composed largely of a type of mold called *Oidium lactis*. When grown under such conditions as found in this factory it assumes an elongated, feathery form which is quite distinctive in appearance from that of the mold which grows on tomatoes.

In the examination of some samples of tomato products this characteristic type of growth has been of practical use in indicating the existence of foul or dirty factory conditions.

Inspection of the cleaning equipment of the factory showed that it was entirely inadequate. Too great reliance was being placed in the supposed efficiency of the steam hose, and there was lack of other proper cleaning apparatus. The cleaning process also was made more difficult because rough lumber had been used for flights on conveyors, for paddles of the cyclones, and in other places. In addition to these difficulties some of the corners were inaccessible and poorly constructed. After suitable cleaning utensils were obtained and certain changes made to facilitate the cleaning operation for the work-

<sup>1</sup> Under proper factory conditions it is possible to maintain the following maximum counts: Mold in 25 per cent of the microscopic fields; yeasts and spores per 1/60 cubic millimeter, 25; bacteria per cubic centimeter, 25,000,000. (See U. S. Dept. Agr., Bur. Chem. Circ. 68, Tomato Ketchup under the Microscope, pp. 4, 5, 6.)

<sup>2</sup> By Dr. Charles Thom, Bureau of Chemistry.

men the high count was immediately lowered and remained low during the rest of the visit.

Tests of the ketchup manufactured by this factory were made periodically during the stay and were distributed over 8 days. The first four tests were made prior to the general cleanup. The sample used in the fifth test was taken from the first batch of ketchup made after the cleaning was completed. About one-third of the molds in this sample were distinctly of the form which indicates dirty apparatus. They were the filaments dislodged during the cleaning process which had not been fully rinsed out during the washing and hence were carried over in the first kettleful of the product. The last four tests were made during the next three days.

TABLE 1.—*Microscopical examination of tomato ketchup before and after the installation of adequate cleaning equipment and methods.*

| Test No.                                     | Per cent of fields with molds. | Bacteria; million per cubic centimeter. | Yeasts and spores per 1/60 cubic millimeter. |
|----------------------------------------------|--------------------------------|-----------------------------------------|----------------------------------------------|
| 1.....                                       | 45                             | 40                                      | 65                                           |
| 2.....                                       | 66                             | 60                                      | 57                                           |
| 3.....                                       | 64                             | 52                                      | 52                                           |
| 4.....                                       | 54                             | 43                                      | 56                                           |
| Average before cleaning.....                 | 57.2                           | 48.7                                    | 57.5                                         |
| 5.....                                       | 30                             | 9                                       | 21                                           |
| 6.....                                       | 16                             | 10                                      | 15                                           |
| 7.....                                       | 21                             | 10                                      | 10                                           |
| 8.....                                       | 15                             | 8                                       | 7                                            |
| 9.....                                       | 20                             | 7                                       | 13                                           |
| Average after cleaning, excluding No. 5..... | 18                             | 8.7                                     | 11.2                                         |

A study of Table 1 emphasizes the change in the counts between those made before and those made after cleaning, in that the counts have been reduced in the case of mold to about one-third and of bacteria and of yeasts and spores to about one-fifth.

The question may arise in the minds of some readers as to whether the marked change shown in the counts might not have been the result of other influences than the cleaning. The only other change made was a minor one in the system of sorting. In Table 2 are given the results of efficiency-of-sorting tests. The method of making these tests is described in detail on page 18. The tests were made on the sorted and washed stock ready for the crusher and represent the approximate percentage of decay that was going into the finished product. The data in Table 2 show that the average percentage of decay during the first 5 days was 1 per cent, while during the last 3 days (the after-cleaning period) it was 0.94 per cent. Obviously these figures are negligible in accounting for the marked changes observed in the counts.



TABLE 2.—*Efficiency-of-sorting tests.*

| Date.         | Hour of test.  | Percentage of decay. | Date.         | Hour of test.  | Percentage of decay. |
|---------------|----------------|----------------------|---------------|----------------|----------------------|
| Sept. 22..... |                | 2.20                 | Sept. 26..... | 8.00 p. m....  | 0.37                 |
| Do.....       | 9.30 p. m....  | 1.60                 | Do.....       | 10.15 p. m.... | .93                  |
| Do.....       | 10.45 p. m.... | 1.50                 | Sept. 29..... | 10.00 a. m.... | 1.70                 |
| Sept. 23..... | 11.45 p. m.... | .81                  | Do.....       | 5.30 p. m....  | 1.35                 |
| Sept. 24..... | 9.15 a. m....  | .87                  | Do.....       | 8.00 p. m....  | .50                  |
| Do.....       | 5.00 p. m....  | .50                  | Do.....       | 8.30 p. m....  | .43                  |
| Do.....       | 9.00 p. m....  | .50                  | Do.....       | 11.00 p. m.... | .75                  |
| Do.....       | 11.30 p. m.... | 1.10                 | Sept. 30..... | 10.30 a. m.... | .75                  |
| Sept. 25..... | 10.00 p. m.... | .75                  | Do.....       | 11.40 a. m.... | .55                  |
| Sept. 26..... | 11.45 p. m.... | 1.10                 | Do.....       | 7.30 p. m....  | 1.00                 |
| Do.....       | 3.45 p. m....  | 1.00                 |               |                |                      |

During the visit at the plant personal attention was given to the cleaning operations. Wherever possible without handicapping the operations of the factory, changes were made by which the apparatus was more easily and effectively reached for cleaning. In some cases wooden piping was changed, doors put in conveyors, pulp boxes made removable, and other changes were made by which the workmen could clean the various parts more quickly and efficiently.

After these improvements had been made a change was noticed in the odor about the factory, especially when the steam hose was in use. The offensive, fetid odor, which had been noticeable in the rising vapors whenever the steam hose was used, almost wholly disappeared, and in its place came the characteristic odor of fresh tomato pulp.

#### Factory No. 2.

A faulty sorting system was the cause of the high counts present in the product manufactured by another factory visited by the bureau's representatives. This condition is more general than the existence of inadequate cleaning systems.

It was brought to the attention of the Bureau of Chemistry that this factory was having difficulty in maintaining low counts on its products. On visiting the plant it was found that the tomatoes were dumped into a soaking tank, from which they were carried up by a conveyor and fed into a rotary washer, covered with a screen of too fine a mesh to allow its being as efficient in removing soft rot as is necessary. From this washer the tomatoes were fed to the sorting apron. This apron was so arranged that at intervals along its length a portion of the main stream of tomatoes was diverted through the scalding boxes and out upon the peeling tables. Three sorters were working at the main sorting apron, but were so stationed that the tomatoes diverted to the first table received little or no sorting inspection. Those for the second table received some attention, while those for the third had the greatest amount. The sorters also were trying to do trimming work. The result was that many spotted tomatoes

were not sorted out. Tests made for the percentage of rot in the sorted stock showed it to vary from about 0.1 per cent to over 2.5 per cent of decayed material. The apron was moving at a rate of 78 feet per minute. During the three days that tests were made at the plant several changes were instituted, among which were slowing down the rate of the apron, securing more women for the inspection service, and dividing them into squads. One squad did nothing but sort out the spotted tomatoes and put them in buckets the contents of which were trimmed by the second set to remove the rot. Tests on the efficiency of sorting under the changed conditions gave a range of from no appreciable amount of rot to 1.3 per cent.

### Factory No. 3.

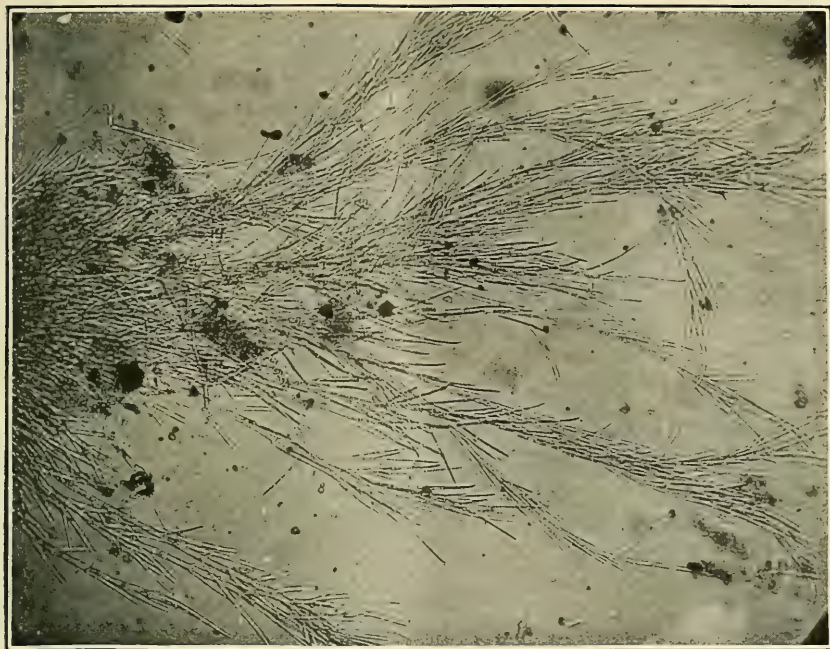
A visit made to still another plant, some of the product of which had been condemned the previous season, showed that the tomatoes were passing through one of the washers and scalders at the rate of 490 bushels per hour. Five young boys, between the ages of 13 and 15, were working at the sorting table. A test of the stock being fed to the sorting table gave about 16 per cent of rotten material. A similar test after sorting gave about 7.5 per cent. All the waste from the tomatoes removed at the peeling tables went into the cyclones for pulp making.

### WASHING.

During the last few years various systems and devices have been tested under factory conditions and a mass of data has been collected bearing upon so many of the practical questions concerned in the production of a clean, sanitary product that it is proposed to discuss here the more important of these operations.

Any one familiar with the canning industry must have noticed the changes that have taken place in recent years and the improvements that have been made in tomato-washing machinery. The choice of a proper washing system requires a knowledge of the specific conditions under which the system is to be operated in each case, since a system that works satisfactorily under one set of conditions may be inadequate elsewhere.

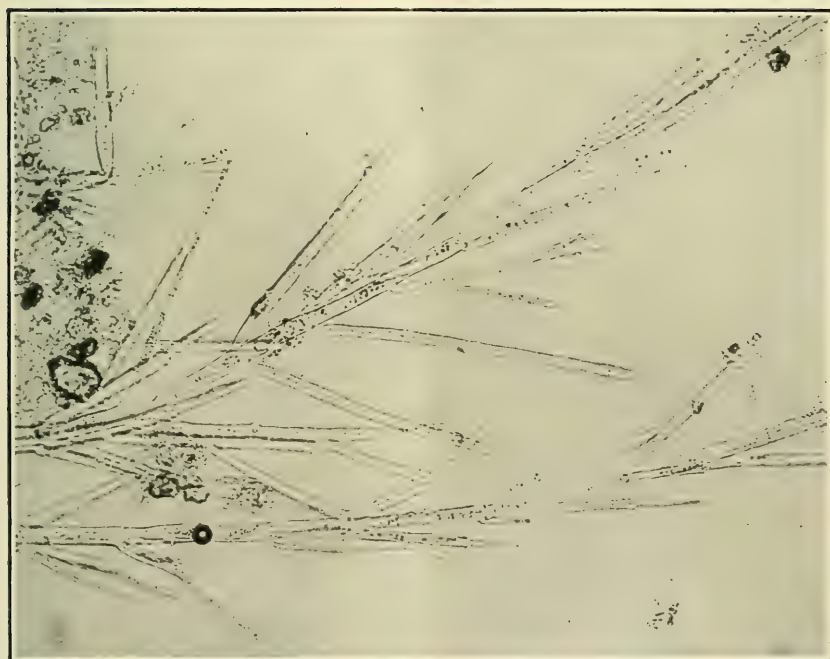
In some parts of the country tomatoes are grown on a soil which has an abundance of sand in it and little clay. Tomatoes grown on such land are fairly readily cleaned by a good spraying apron washer. In other parts of the country the soil consists of a sticky clay loam, which clings so tenaciously as to make its removal by the spraying system alone very difficult. In such cases some sort of rubbing method is highly desirable. It is under such conditions that the rotary washers are efficient. Factory owners sometimes have been found who have been deceived as to the efficiency of their



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FIG. 1.—MOLD FROM SLIME ON INSANITARY APPARATUS. (MAGNIFIED 100 DIAMETERS.)

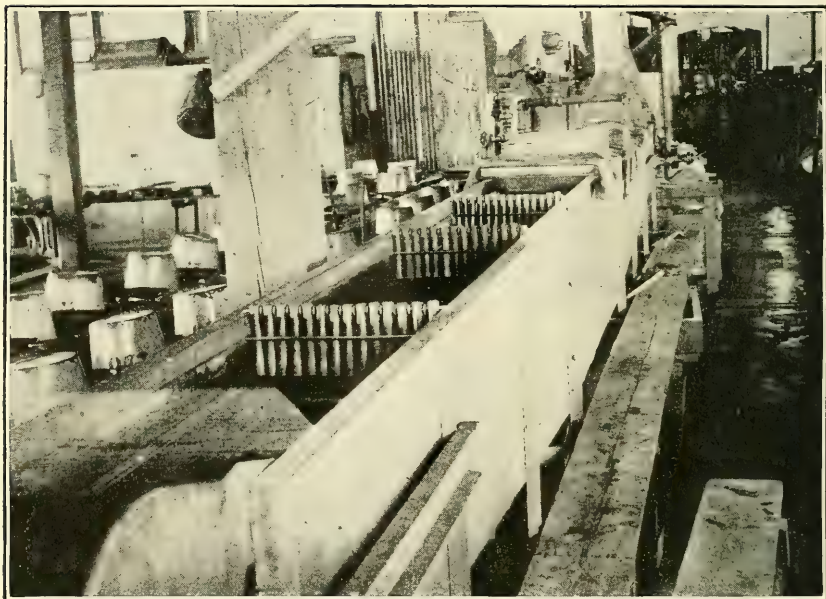
Note the feathery character.



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FIG. 2.—MOLD FROM SLIME ON INSANITARY APPARATUS. (MAGNIFIED 300 DIAMETERS.)





BCH2326

TOMATO TURNING DEVICE ADAPTED TO SIMPLE APRON SORTING TABLE.

washers, because a thin coating of dirt on the skin of a tomato is less evident when the tomato is wet than when it is dry. Tomatoes that may appear fairly clean when wet may still show a thin, adhering coat of soil if allowed to dry.

The principal types of washers in use are the following: (a) dump hopper; (b) worm (helicoid); (c) spray apron; (d) rotary; (e) paddle agitator; (f) air blast (geyser); (g) cascade.

(a) The dump hopper is now used by only a few small packers. It has practically nothing to recommend it as a washer.

(b) The old-style helicoid worm washers also are being replaced rapidly by the more modern types.

(c) In the plain apron washer the tomatoes are carried on an open-work apron through an inclosed chamber in which are strong sprays that strike the tomatoes at various angles. This type of washer does satisfactory work provided the water pressure is high enough (some advise 100 pounds or more per square inch), and the soil on which the tomatoes are grown is not of a very sticky character. If a high pressure is used the apron washer assists materially in eliminating soft rot spots, although, of course, it should not be expected to do the work which properly belongs to the sorters. The type of nozzle used on these machines, however, offers opportunity for improvement. A nonclogging, flat spray form is much needed. The common spray form of nozzle usually employed does not deliver the force of the water evenly. Since the water is delivered in a circular form the tomatoes passing along the edges of the circles get the force of the stream for a longer time than those going through nearer the center. The orifice of emission of the water in this type is so narrow that it clogs quickly unless the water supply is very free from solid particles such as scale from the inside of the water pipes. Nozzles working on the impact principle do not seem to be so subject to these objections.

(d) The rotary washer consists of an inclined cylinder covered with a wire screen of 1-inch mesh. It is very commonly used and generally gives good results. Its advantages are that it rubs the tomatoes against each other, thus loosening the dirt, and it does the washing with a less expenditure of water than most of the other washers that give satisfactory results. Furthermore, it will remove some of the soft-rot tomatoes. The principal objection urged against it is that the manner of its operation tends to crush some of the very ripe tomatoes, which may be sound but so ripe as to be tender.

(e) In the paddle-agitator washer the tomatoes are dumped into a tank of water where they float and are agitated by slowly revolving paddles, which cause the tomatoes to rub against each other, thus loosening the dirt. At the same time the tomatoes are worked along toward the conveyor, which removes them from the tank. As they

are carried out they pass under water sprays which give them a final rinsing.

(f) The air-blast or geyser washer works on the same general principle as the preceding type, but produces the agitation by blasts of air entering the tank at or near the bottom.

(g) In the cascade washer the tomatoes are carried up a tight-bottomed conveyor inclined at an angle of  $30^{\circ}$  to  $50^{\circ}$ . Near the top are the inlets for water which emit a sufficient amount to produce a vigorous flow down over the ascending stream of tomatoes. Although it is a good rinser, it is not sufficient alone to remove thoroughly the sticky soil from the fruit.

### SORTING.

#### ITS IMPORTANCE.

A careful consideration of the causes of failure in making clean, sound, sanitary tomato products shows clearly that more difficulty is experienced in effecting satisfactory washing, prompt handling, and efficient sorting than in any of the other phases of the manufacturing process. Sorting is the most important of these operations, in which the judgment of the workman plays a considerable part. Satisfactory washing is largely a question of proper operation of a mechanical device. This may be said also of many of the other operations about the factory, but so far no mechanical contrivance for separating the decayed from the good parts of the tomatoes has been placed upon the market. This operation must still be performed principally by hand. Although some washers, if properly constructed and operated, will assist in removing the badly soft-rotted tomatoes, efficient hand sorting must be employed if a uniformly good, sound product is to be obtained.

Experience has shown that in factories where the tomatoes are used only for peeling stock and where all the trimmings are thrown away sorting is an unnecessary expense. In the making of pulp of any kind, however, efficient sorting is absolutely necessary. Otherwise there can be no assurance of producing a uniformly sound product with low counts of microorganisms.

The conditions observed and the results obtained in various factories show that there is little, if any, choice between sorting the tomatoes before and after washing. Some of the best, as well as some of the poorest, results were obtained in factories where one or the other of these methods was employed. Approximately two-thirds of the plants visited during the seasons of 1915 and 1916 that did any sorting at all were using the wet method, and one-third the dry method. In order to remove clinging pieces of partially decayed tomatoes, the tomatoes always should be subjected to a washing or



rinsing after sorting, even though the principal washing has been done before sorting.

#### SORTING SYSTEMS.

The various sorting systems in operation may be designated as (a) table, (b) simple apron, and (c) divided apron. These systems are not kept entirely distinct, however, but frequently overlap in one particular or another.

(a) In the typical table system the tomatoes are dumped upon a stationary table or sorted directly from the crate or basket. The tomatoes are picked out by the sorters who are stationed around the table, and after being examined are tossed into suitable containers, from which they are emptied from time to time into the washers. The decayed tomatoes or parts thereof are removed and rejected. One advantage of this system is that by examining the sorted stock in each container the efficiency of the individual sorters can be determined more readily than by any of the other systems. As a rule it is a fairly effective system, but usually is more expensive than any of the others.

(b) In the simple apron conveyor system the tomatoes are placed upon a slowly moving, horizontal apron which carries them along in front of the sorters, who are supposed to remove all tomatoes that are entirely or partially decayed. Those not picked out constitute the stock finally used in the manufacturing process. By this system the tomatoes theoretically are subjected to as many inspections as there are sorters to the apron. With good sorters and where proper conditions of feed, rate of movement, and lighting are maintained this is practically true, but emphasis must be laid upon the observance of these details if satisfactory results are to be attained.

Under normal conditions, where proper attention is given to details of feeding and lighting, the apron conveyor system has been found to yield as good results as any that has been devised. This is true for two reasons. In the first place, only those tomatoes that have decayed parts need to be picked up and taken out. During the last two seasons more than 100 tests were made on the unsorted stock in about 30 different factories in various parts of the tomato-producing sections east of the Mississippi River. These tests have shown that from 0.4 per cent to 81 per cent by number of the tomatoes were decayed, in whole or in part, to such an extent as to require trimming or total rejection. The average by number was about 25 per cent. This means that in an average bushel<sup>1</sup> of tomatoes 58 must be removed and rejected either in whole or in part.

The second advantage of this system is that if one of the sorters is inexperienced or becomes a little lax in the work the fault is more

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<sup>1</sup> The average number of tomatoes per bushel as determined by 174 tests made in 1916 was 229.

likely to be compensated for by the carefulness of the other sorters than in the case of any of the other systems. This, however, should not be used as an excuse for putting unreliable sorters on the apron.

The width of aprons used varies greatly, ranging from 8 inches to 4 feet. To get the best results the aprons should be narrow enough for the sorters to reach easily across the entire width. The most convenient and practicable width has been found to be from 18 to 20 inches.

Even greater variation is found in the rate of movement of the apron. Tests on the rate of speed in different plants showed a minimum rate as low as 16 feet per minute and a maximum as high as 140 feet. The speed of the apron should be retarded sufficiently to permit careful observation of the individual tomatoes and to allow the sorters sufficient time to reach for and remove those with rotten spots. Observation of a large number of sorting aprons in operation has shown that it is impossible to obtain good results with a speed exceeding 25 feet per minute.

(c) In the divided-apron system the tomatoes are dumped upon a conveyor very similar in construction to the simple apron, but usually somewhat wider. Over this conveyor a guide is suspended which divides the stream of tomatoes into two parts, one on each edge, and leaves also a vacant space through the center of the apron. The sorters stand beside the apron, pick out the good tomatoes, and toss them over into the middle section of the apron. All the tomatoes not thrown over into the middle section pass into the waste at the end of the machine. The good tomatoes pass on into washing or rinsing systems. A modification of this system is to remove the bad or spotted stock to the middle section from which they pass into the waste.

Each tomato, theoretically, is subjected to a scrutinizing inspection, but actually, when the sorters are inspecting rapidly, they will pick up some of the tomatoes and toss them into the center without taking the trouble to turn them over to see the underside. The fact that by this system all the tomatoes, both good and bad, must be actually handled contributes materially to the inefficiency of the system, as about 75 per cent of the entire stock are sound. It necessarily follows that, as a rule, a larger corps of sorters will be needed than in the simple apron system, where only tomatoes with decayed parts have to be handled.

In constructing a sorting apron of either type the manufacturer's first problem is to plan one that will meet his requirements as to capacity. A number of tests made on the area a bushel of tomatoes will cover when laid out in a layer one tomato deep showed that, in general, the larger the tomatoes were the smaller was the area covered. The tests made showed a variation of from approximately 7 to

12½ square feet per bushel, with an average of about 9½. As the tomatoes should be fed onto the apron so as to leave at least one-half of the space uncovered, a space of about 18½ square feet should be provided for each bushel. This would mean that a sorting apron 18 inches wide and moving at the rate of 25 feet per minute would have a capacity of about 120 bushels per hour and when handling average stock would require the services of six efficient sorters. On this basis a separate sorting apron would be required for each 1,200 bushels handled per 10-hour day. Such an arrangement provides for the most efficient utilization of equipment. In some factories visited the arrangement was so poorly planned that the apron was running ten times faster than was necessary for handling the volume of stock. In other factories the tomatoes were run through at from five to six times the normal capacity of the machine and the number of sorters was insufficient to handle them under proper conditions.

#### SORTING SYSTEMS THAT HAVE FAILED.

In the past the practice of making pulp from peeling-table waste was not uncommon. Much of this pulp, in a more or less concentrated condition, was placed in barrels and disposed of for making cheap ketchup. The careless methods employed resulted in many condemnations of the product under the Federal Food and Drugs Act because the product was decomposed, in whole or in part. As a result of the Government's campaign against adulterated tomato pulp, some of the evils of the practice have abated.

The pulp commonly used for low-grade ketchups sold at from 75 cents to \$2.50 per barrel, most of it selling for from \$1 to \$1.75. At these prices the manufacturer received only about enough to pay for the disposal of the waste which otherwise was an item of expense. When it is realized that the stock from which tomato pulp is made may contain 20 per cent of rotten tomatoes and yet not give to the finished product such plain evidences of their presence as to be detected by the average consumer, it is easy to understand the temptation and opportunity for negligence and carelessness in the manufacture of the product.

Some firms, by modifying their methods of manufacture, have been attempting to produce from trimmings an article which would be satisfactory under pure-food laws, but only a few have been successful, and these only in part. An examination of the prosecutions brought against adulterated tomato products during the last six years will show that most of these products were made from trimming stock. A recognition of these facts has raised the question whether it is possible to make a satisfactory pulp from the trimmings. It is possible to do this, but the added labor required makes it doubtful whether it is profitable. As the tomatoes must be sorted and handled



with unusual care if the trimmings are to be used for pulp, about one-eighth as many sorters as peelers must be employed.

Various methods have been tried unsuccessfully in different plants in the hope of avoiding the labor and expense involved in a thorough sorting of the stock before it passes to the peeling tables. An account of the least successful methods follows.

One method consists in furnishing each peeler with two buckets, one for sound trimmings, the other for decayed portions. The peelers are paid only for the peeled tomatoes. Hence, very little or no attention is given to sorting the good from the bad portions of the trimmings. Even if the sorting were done carefully there would still be the objection that the good portions had been contaminated by contact with the partially rotten portions during the handling after scalding and before peeling.

Another method tried by some manufacturers is to rinse the trimmings themselves. This is unsatisfactory for the following reasons: The washing results in a great loss of material; the trimmings on account of their bulk can not be washed effectively; and no washing system has been devised which will remove certain types of decay.

A third method is to inspect the trimmings after they leave the peeling tables and to remove the bad portions. A small proportion can be picked out in this manner, but the amount is so small that the system is of very slight value. After a large number of cut pieces, such as occur in trimmings, have been dumped together it is a physical impossibility to sort out any but the more solid portions, such as large pieces and those of dry or black rot. The pieces of soft rot become mashed and contaminate the whole mass and can not be removed.

#### UNIFORMITY AND RATE OF FEEDING.

The rate at which the tomatoes are fed upon the apron is an important factor in the efficiency of sorting. Tomatoes frequently are fed so irregularly that it is impossible to obtain good results.

Observations were taken at several plants for the purpose of determining what variation occurs in feeding the tomatoes to the sorting apron. The data from one of these inspections are given in Table 3.

TABLE 3.—*Variation in rate of dumping tomatoes into the washer.*

| Time.                | Bushels. | Time.                | Bushels. |
|----------------------|----------|----------------------|----------|
| First 2 minutes..... | 8        | Next 6 minutes.....  | 0        |
| Next 3 minutes.....  | 0        | Next 1½ minutes..... | 4        |
| Next 2 minutes.....  | 9        | Next 1½ minutes..... | 0        |
| Next 1 minute.....   | 0        | Next 1 minute.....   | 4        |
| Next 1 minute.....   | 4        | Next 9 minutes.....  | 0        |

This series of observations, which extended over a continuous period of 28 minutes, shows a variation of from 0 to  $4\frac{1}{2}$  bushels per minute. The table shows that during the 28 minutes there were five periods of from 1 to 9 minutes each (aggregating a total of  $19\frac{1}{2}$  minutes) during which no tomatoes at all were dumped into the washer. From the washer the tomatoes were removed by a conveyor to the sorting apron. This tended to equalize the variation somewhat, but there was still great irregularity as the tomatoes were delivered finally for sorting. Although the average rate was only about 66 bushels per hour, there were periods when the observed rate amounted to 270. Such variation makes it practically impossible to obtain uniform results in sorting.

In dumping directly on the sorting apron the workmen often become careless and the tomatoes pass to the sorters in piles interspersed with vacant areas. In some plants one of the workmen is assigned to the task of regulating the rate at which the tomatoes are fed from the dumping board to the apron, but even this is not wholly satisfactory. An attempt has been made to overcome this difficulty by providing a mechanical device in the form of a feeding hopper, and although this device has not been tested thoroughly, it gives promise of relief. This feeding hopper consists of a short conveyor 18 inches wide and about 42 inches long, inclosed at the sides by boards extending 6 inches above the apron. It is so regulated that it travels 3 feet per minute. The conveyor or hopper thus made is kept rounding full and so placed as to deliver the tomatoes to the sorting apron with as little drop as possible. With these specifications as to size and speed, such a feeder, if kept full, will deliver 120 bushels of tomatoes per hour to the sorting apron at a regular speed. This is about the amount that can be handled satisfactorily on a sorting apron operated by 6 good sorters. Although this device as yet has been tested only in an experimental way under factory conditions, the results appear encouraging.

#### TURNING DEVICES.

For good sorting it is important that during the process all sides of each tomato be subjected to inspection. In 1911 the writer pointed out<sup>1</sup> the desirability of a mechanical device to turn the tomatoes over while they are on the apron. Some firms manufacturing machinery and several packers have undertaken to accomplish this in various ways. Of the forms applicable to the simple apron a certain device used in one plant has such merit that a description of it should prove valuable. Its simplicity, cheapness, and effectiveness, together

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<sup>1</sup> Tomato Ketchup under the Microscope. U. S. Dept. Agr., Bur. Chem. Circ. 68, Feb. 13, 1911.

with the fact that it can be made by the mechanic of almost any plant, are important points in its favor.

For an apron 18 inches wide, 14 pieces of  $\frac{3}{4}$ -inch iron pipe (1 inch outside) were cut, each piece about 7 inches long. About one-half inch from one end of each piece a hole was drilled through the pipe large enough to permit of the pipes being strung on a  $\frac{1}{4}$ -inch steel rod. In order to insure freedom of movement a thin washer was placed between each pipe and the one next to it. The whole set was then suspended by means of the steel rod across the sorting apron with the lower ends one-half inch above the apron. A back-stop rod is put in behind the set to prevent the pipes from swinging back past the center. This was found necessary to prevent them from swinging so far back as to strike and gouge the oncoming tomatoes. Plate II shows a sorting apron fitted with three sets of pipes, thus allowing for one set between each pair of sorters. In operation the weight of the pipes is sufficient to roll the tomatoes over as they pass under.

In order to obtain satisfactory operation it is most important that the tomatoes do not cover more than 50 per cent of the apron area, otherwise they do not have room to turn properly. A test at one plant showed that 70 to 80 per cent of the tomatoes were turned each time they passed under a set of the pipes. It was found also that this turning device worked better on the open metal apron than on the canvas or rubber type, owing to the fact that the tomatoes slipped badly on aprons made of canvas or rubber.

#### LIGHTING THE SORTING TABLES.

The matter of providing suitable lighting for efficient sorting often has been neglected. In all too many instances there are no top lights, no provision is made for artificial lighting on dull days, or the workmen stand in their own light or labor under similar difficulties. Sorting requires quick observation and action and the workmen should have every possible advantage. Certain manufacturers have expressed gratification on noting the increased facility with which the tomatoes on the apron could be examined after their plants had been lighted properly.

The tomato-packing season comes at a time of the year when many days are cloudy. Hence, in planning an equipment provision always should be made to meet the most unfavorable conditions. The most desirable form of light is top light. This usually can be obtained at small expense by putting in a skylight. Where this is impracticable, two 100-watt electric lights with good white reflectors suspended 4 feet over each table give satisfactory light. In order to make provision for dark days it is desirable to have some such form of artificial lighting, even when the sorting room has a skylight. The



lighting should be so arranged that the shadows of the workmen do not fall upon the table. The walls and ceiling of the sorting room or shed should be painted white or whitewashed.

#### SELECTION OF SORTERS.

Greater care should be exercised in the selection of sorters than in the selection of any of the other laborers connected with the manufacture of tomato products. Some packers apparently have made the mistake of thinking that anyone who was not definitely employed elsewhere was good enough for sorting. Sorters, however, should be men or women (women usually have proved more satisfactory) old enough to be responsible and dependable, young enough to be still active and energetic. Young people not thoroughly responsible should under no conditions be intrusted with this important work. More harm can be done by one or two careless persons at the sorting apron than almost anywhere else in the plant.

The work is of a kind that requires perhaps closer attention and application than any other work about the plant, and might well be called "skilled labor," since efficiency in producing the best results comes from practical experience. Because of the close attention required of the workers it is one of the most fatiguing operations about the plant, and it is believed that a small bonus per hour to the persons selected to do this work would serve as an incentive to more painstaking work. In some factories visited, however, the sorters were paid only half or two-thirds as much per day as the peelers. Such shortsightedness in factory management is certain to lead to dissatisfaction and carelessness.

Because of the fatiguing character of the work, it would be wise where feasible to work the sorters in shifts of not over three hours each. The sorting should be superintended by a person who has proved himself highly efficient in that line of work or by one who is alert and has a discriminating mind and is able to handle workmen tactfully.

Where the simple apron system is used it is best to place the most efficient sorters last, in order that the final inspection may be made the most critical.

#### VOLUME SORTED.

The volume of tomatoes handled by one sorter is dependent upon several factors, among which the most important are the condition of the tomatoes, the system of sorting used, and the efficiency and experience of the sorter. With average stock it is impracticable to get good results by the table system if the tomatoes are delivered at a rate of more than 5 to 8 bushels per sorter per hour. With the

apron systems 20 to 25 bushels per sorter per hour have been about the practical limit for obtaining uniformly good results. Packers heretofore have given this point far too little consideration. It has been observed in some factories that the tomatoes were passing through at the rate of 200 bushels per sorter per hour. It is quite evident that little or no benefit can result from the operation of a sorting table under such conditions.

In order to impress upon producers the importance of handling the crop properly, some packers have put into operation a "loss-off" system by which they pay for the tomatoes on the basis of the sound tomatoes, allowing the presence of only a nominal proportion of spotted ones.

#### EFFICIENCY OF SORTING.

Practically all plants have some kind of sorting system, but experiments and observations in different plants show a wide variation

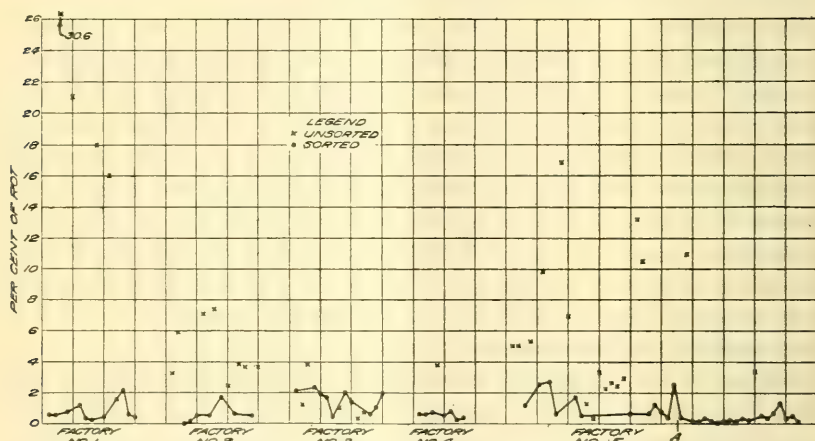


FIG. 1.—Efficiency sorting chart. Each cross or dot represents the result of an individual test and indicates the percentage of rot found.

in the efficiency of such systems. In some plants the sorting is done effectively, while in others the work is performed so poorly as to be practically valueless.

In order to obtain a numerical expression of the efficiency of sorting, the following method was employed: To secure the samples small portions of the stock were taken from the stream at intervals of about 15 seconds until a total sample of 20 to 40 pounds had been secured. The tomatoes in the composite sample were then examined critically for decayed portions. The objectionable parts were cut out, weighed, and their percentage calculated. Tests made under a variety of conditions in different factories showed that with proper equipment and control the percentage of decay can be maintained at 1 per cent or less. For purposes of com-

parison tests also were made on some of the unsorted stock. The results of the tests from a few typical plants are shown graphically in figure 1. The tests at each factory are plotted in the order made, but they were not made at equal intervals.

Factory No. 1 illustrates a case where the stock used was of very poor quality but, owing to the excellence of the sorting and washing systems, the decay was kept down to an average of 0.8 per cent, although two or three of the tests ran rather high.

Factory No. 2, which had experienced trouble in producing a sanitary product, adopted in 1916 a system of sorting and washing that very much improved the character of the product. In this case the average of the tests made for amount of rot was 0.5 per cent, with one test running up to the high point—for sorted stock—of 1.7 per cent.

The table system of sorting was being followed at factory No. 3. The work, however, was done so ineffectively that tests on the sorted stock showed about 1.4 per cent of rot as against about 1.5 per cent for the unsorted, so that there was practically no improvement. The average amount of rot present was one and three-quarters times as much as in factory No. 1, although the condition of the unsorted stock at factory No. 1 was fourteen times as bad as at factory No. 3.

At plant No. 4 the conditions as to sorting were found in 1910 to be very unsatisfactory. Since that time extensive experiments have been made, until in 1916 the improvement shown in the chart was observed. The average of the seven tests made on two days was about 0.5 per cent.

The chart also shows the result of tests made during three days at factory No. 5. At the beginning of the experiment the plant had a number of serious defects in its sorting system. Later, several changes were made in the system and the factory was operated on a more approved method with striking results. The point when the changes were adopted is shown in figure 1 by the letter A. The average of the tests on the sorted stock prior to A was 1.26 per cent of rot; of the tests made subsequently, only 0.28 per cent.

Data collected in many factories showed that in samples of unsorted stock examined the percentage by weight of rotten material varied from practically nothing to over 30 per cent, while the average in the whole series was about 5.5 per cent. The percentage of rot in the sorted stock (including the badly sorted as well as the thoroughly sorted) varied from practically zero to over 7 per cent, while the average was about  $1\frac{1}{3}$  per cent.

The percentage of rot by number was also determined during the season of 1916 in most places in addition to the percentage by weight. Although not so reliable as the determination by weight, it does at



times serve as a quick, rough method of arriving at a knowledge of the character of the stock.

The data obtained show that on unsorted stock the percentage by number of tomatoes with rotten spots is approximately six times as great as the percentage by weight of decayed material. In seeking to estimate the proportion of decay in this manner, however, in the practical testing of stock the results can be regarded only as a rough approximation, since the variation in individual cases is very wide, ranging from a ratio of about 2 in some cases to 15, and in a few instances even higher than this. If this method is to be used in a practical way it should be used only where the percentage by number of decayed tomatoes does not exceed about 15, since even in that event it would indicate very roughly  $2\frac{1}{2}$  per cent of rot by weight. The factor, as a rule, becomes smaller as the percentages increase, owing to the relatively higher proportion of tomatoes with large spots. In the samples of sorted stock the average ratio of percentage of spotted tomatoes by number to percentage of rot by weight was about 10 to 1.

These relationships indicate that the rotten or spotted condition in unsorted stock averaged one-sixth of the mass of the tomato in which found, while in the sorted stock it averaged about one-tenth of the mass.

#### COST OF SORTING.

The question of the cost of sorting is important to the manufacturer. The wage commonly paid for this type of labor is about 15 cents per hour. The output by the table system of sorting ranges from 5 to 8 bushels per sorter-hour. Hence, the minimum cost by this system is about 2 to 3 cents per bushel. The investment for sorting equipment in this system is practically nothing.

By the apron system, good effective sorting can be made at the rate of 20 bushels per sorter-hour, thus reducing the labor cost to about three-fourths of a cent per bushel. This is simply for the removal of the tomatoes that are more or less decayed and that must be trimmed if any part is to be retained for use. The trimming process itself is believed to be usually a self-paying proposition.

#### TRIMMING.

Some packers have been observed to discard the whole of any tomato that showed a decayed spot. Tests made under factory conditions, however, prove that this is a wasteful practice, since the average amount of decay on unsorted stock is only about one-sixth of the whole tomato. Hence, to remove absolutely all traces of decay from each tomato, usually less than one-third of the tomato would need to be cut out. The remainder of the tomato would be entirely

suitable for use. In the apron system, however, it is strongly advised that if trimming is to be practiced it be done by a different set of employees from those who do the sorting, for if the sorter is required both to sort and trim at the same time his attention will become divided and he will pass many bad tomatoes.

Tests made at one plant where the work of sorting and trimming was done by two sets of workers showed that one trimmer reclaimed  $43\frac{1}{2}$  pounds of good stock in 25 minutes, or 104.4 pounds per hour. At the price then paid for tomatoes the quantity that was saved compensated for more than one-third of the expense of the efficient sorting and trimming being done at the plant.

### PULPING.

The pulping systems in use may be classified as (*a*) cold and (*b*) hot. By the cold system the tomatoes are not cooked, but are put through the cyclones before or after passing through a chopping or crushing device. This is the usual system followed in making pulp from trimmings, although the scalding of the tomatoes for peeling slightly cooks the surface tissues. When the stock is scalded for peeling, and occasionally for whole-tomato pulp, the light cooking makes possible a cleaner separation of the pulp from the skin than is secured by the typical cold method.

By the hot system the tomatoes are partially cooked before going to the cyclone. This cooking undoubtedly gives a larger yield of pulp from the stock and tends to arrest or decrease the growth of microorganisms. Some manufacturers claim that they obtain a redder product by the cold than by the hot system, but the observations of the bureau seem to indicate no marked difference in the color of the product that may be attributed fairly to either system.

### PULP-MAKING SYSTEMS.

The only places where the making of satisfactory trimming pulp has come under the observation of the department are those factories in which the tomatoes for canning were very carefully sorted before going to the peeling tables. This is done preferably before the tomatoes have been scalded, as after scalding they are too hot to be handled with any comfort, even when given the customary "chilling."

Some canners had the sorting done by men who had some other duties around the scalding or washer. This, however, is very undesirable, for if satisfactory results are to be obtained it is important that even more critical sorting be maintained than in the making of whole-tomato ketchup or pulp. This necessity for care is equally applicable to all the details of pulp making, such as method, speed of apron, capacity, personnel, and efficiency of the sorters, and prompt-

ness in handling the product. When proper attention is given to these details a satisfactory product can be obtained, but it is in the exercise of the care required that many packers have failed.

Why should the manufacturer desire to turn his trimming waste into pulp? Tests made at various factories have shown that 30 per cent or more of the weight of the tomatoes as received at the factory goes into the waste known as trimmings. An examination of

ordinary trimmings shows them to consist of: (a) the skins from peeled tomatoes; (b) the stems and coarser part of the cores from around the stem end of the fruit; (c) the decayed and rotten parts cut out from the otherwise good fruit; (d) tomatoes wholly decayed; and (e) small tomatoes, and others of such size or shape that it would be unprofitable to skin them. If the trimmings were in good, clean condition, it is probable that no serious objection could be raised against pulp made from (a), (b), and (e), provided the packages were properly labeled to indicate the origin of the product.

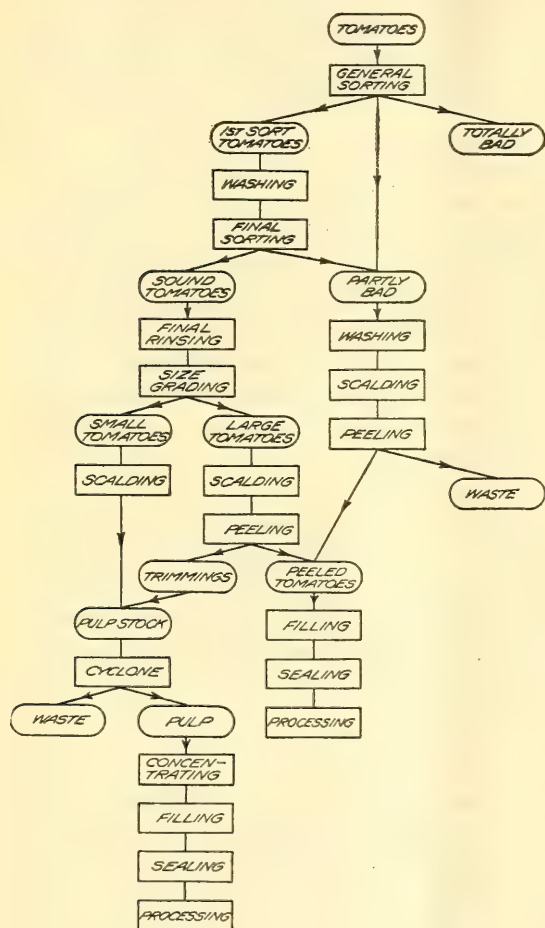


FIG. 2.—Diagram of system for the manufacture of tomato pulp from sound tomato trimmings.

trimmings. Although when properly handled such a system should give a satisfactory product, it is complicated, and the extra labor required in the use of trimmings in the pulp may not in average seasons be compensated by the value of the product resulting.

Because of the fact that a considerable part of the waste comes from small tomatoes which the peelers find it unprofitable to skin,



it has been suggested by some manufacturers that they might, at the start, pass their stock over a mechanical grader to remove all the small tomatoes before the peeling stock goes to the scalding. These small tomatoes could then be put through the proper processes for pulp making while the regular trimmings from the peeling tables would be totally discarded. Figure 3 is a graphic representation of such a system. Although this system appears reasonable and has been tested out by a few firms, sufficient data are not yet available to show its practicability as a commercial proposition. It is much simpler than the system shown in figure 2 and yet provides for the utilization of a large part of the sound portions usually lost in the trimmings.

#### PROMPTNESS IN HANDLING STOCK.

The attention of manufacturers has been called repeatedly to the importance of the prompt handling of tomato stock, especially of the pulp after the sorting, washing, and pulping processes have been started. One of the greatest objections to the old "gravity system" is the delay occasioned at a stage when conditions are most favorable for rapid multiplication of the organisms. In this system stock that otherwise might be satisfactory is held for a period of time under conditions nearly ideal for rapid growth of organisms, especially bacteria and yeasts.

By the gravity method the stock before pulping usually is warmed more or less, according to the fancy of the manufacturer. After pass-

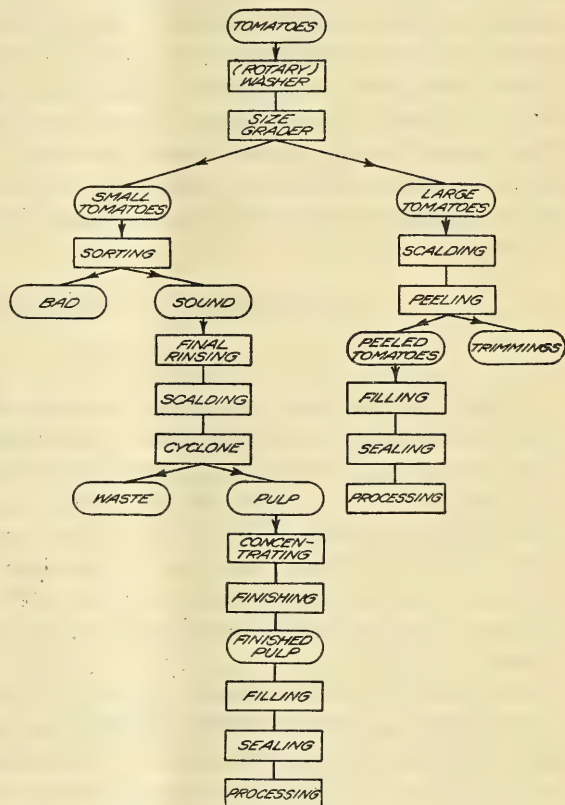


FIG. 3.—Diagram of system for the manufacture of tomato pulp from small tomatoes.

ing the cyclone the pulp is allowed to stand in a tank or vat. In half an hour or so the clear juice begins to separate from the fibrous cellular portions, which tend to rise, owing to the entangled gas. When this stage is reached a stopcock or bung near the bottom of the vat is "cracked" and the juice drawn off. Meanwhile, more pulp usually is added. In this way the pulp is held for varying lengths of time up to half a day or more, which obviously allows some spoilage to take place. Another objectionable feature is that a large part of the soluble solids, which contribute much to the flavor of properly made products, is thrown away. The rapid decline in the use of the gravity method during the last few years, therefore, marks a decided advance in the manufacture of tomato products.

Manufacturers should seek to reduce to a minimum the time required to carry the product through from basket to bottle or can. The slogan "An hour from basket to bottle" expresses a degree of efficiency which should be striven for by every manufacturer and which already is being attained in some factories throughout the country.

## CLEANLINESS IN THE FACTORY.

### ITS IMPORTANCE.

A knowledge of the conditions favorable for growth of micro-organisms serves to emphasize the great importance of cleanliness about a canning factory. To secure normal growth there must be first the spore or a portion of the vegetative part of the organism to start the infection. Then for its development or multiplication there must be a suitable food supply, moisture, and a certain amount of heat. The rate of growth varies for different organisms and is influenced greatly by the nature of the food supply and the degree of heat.

One of the most persistent species of mold occurring around tomato-canning factories is that identified as *Oidium lactis* (Plate I). Molds growing on apparatus impart to it a slippery feel, very different from that which characterizes clean apparatus. A deposit of more or less cheesy consistency usually can be scraped from apparatus having such a feel.

Mold will grow sometimes in many unexpected places, such as on metal and wood conveyors, on cyclone paddles, and in similar places. As its presence always indicates lack of thoroughness in cleaning, it will be seen that proper cleaning is of vital importance if a sanitary condition is to be maintained in the plant. By proper forethought in planning and equipping a factory the difficulties in keeping it clean can be reduced greatly. It frequently happens that in devising, selecting, and installing factory equipment too little thought is

expended in seeing that all parts are so built and placed as to be easily accessible for cleaning. For instance, cyclones which as designed by the makers could be readily cleaned, have sometimes been so installed that effective cleaning was almost impossible. All parts should be accessible for scrubbing, as hose or steam alone can not be depended upon. Care should be exercised to avoid as far as possible all unnecessary angles resulting from careless lapping or matching of parts. Rounded corners can be used at times to great advantage.

#### THE NECESSARY EQUIPMENT.

An inspection of the equipment of some plants often discloses a striking lack of cleaning apparatus, such as water taps, hose, scrub brushes, and brooms. There should be adequate hose facilities for quickly and effectively flushing out machinery and floors. Three or four lines of hose and connections conveniently placed are none too many for an average canning factory. Many factories now have water connections by faucet or short hose within ready reach of each peeler. Such an arrangement allows each worker to clean quickly her own part of the equipment.

A steam hose also should be available. Some persons, however, have been inclined to put too much faith in the efficacy of the steam hose. If intelligently used on machinery that already has been properly scrubbed, it does excellent work in cleaning out loose material from crevices and in sterilizing and heating the metal parts so as to produce quick drying. For cutting out mold and slime on broad surfaces, however, a steam hose usually is insufficient. The average workman is likely to use it for too short a time and on too limited an area.

An ample supply of brushes—not simply one or two—should be readily available. The water-soaked brooms used in some factories should be replaced by stable brushes with stiff, split-rattan or steel-wire bristles. For cleaning wet floors such brushes are easier to use than brooms and are far more effective, as they cut the dirt and slime. The hand brushes also should be of some stiff material which will not, after being used a few times, become water-logged and mat down and simply glide over the surface without loosening the slime. Painter's triangles for reaching into and scraping difficult corners also have been found helpful. One or more flashlights would be of service for inspection and for working in obscure places.

#### USE OF EQUIPMENT.

After an adequate cleaning equipment has been installed a well-systematized plan of operation must be put into effect. Each workman should have an active part in this system. The most effective method for cleaning the floors is to assign three or four active men to



the task. One of these men handles the hose, directing the water where needed; the others loosen the dirt with stable brushes and give the final cleaning. In this way a large area can be cleaned quickly and effectively.

At one plant of moderate size such a plan was observed under operation. The periods immediately preceding luncheon and at the close of the working day were set aside for cleaning. The employees worked with such a degree of system that in 10 minutes the sorting table, washing and scalding machines, peeling tables, buckets, filling machines, cyclones, finishers, and floors were given a thorough cleaning. The reasons for this efficiency were that plenty of water was available, the apparatus was located conveniently, and each person had his or her part of the work to perform. Each woman cleaned her buckets and pans and her part of the peeling table, the sorters cleaned the sorting table, and washing and scalding outfits, while the pulp men were held accountable for the cleaning of their equipment. At the same time those working at the filling and capping machines cleaned their respective outfits. While these operations were going on several men had started flushing and scrubbing the floors at places where they would least interfere with the other employees, and as soon as the others had finished their cleaning the remainder of the floor was finished. The drains were so located as to help facilitate the entire operation.

If any part of the room had not been properly cleaned it was an easy matter to fix the responsibility, since each person had a definite work to perform.

Apparatus if well cleaned should, when wet, be free from any slippery or slimy feel and when scraped should not yield a cheesy deposit. At the close of the day's work the equipment after being cleaned should be left in such position as to permit of ready drainage, ventilation, and drying. These precautions will tend to check the growth of microorganisms. Pails, pans, and buckets should not be stacked, as is frequently done, and the cyclones, as well as the tanks and vats, should be left open.

#### PSYCHOLOGY OF CLEANLINESS.

The old adage "Like begets like" is applicable in factories as well as elsewhere. Where there is intelligent and tactful demand for cleanliness on the part of the factory management there is certain to be a conscious or unconscious response on the part of the employees. A workman has small incentive to adopt cleanly methods, however, if filthy, slovenly, or unsystematic conditions about the factory are the rule. Workmen usually prefer employment in clean surroundings. One factory owner who maintained his plant in good

condition reported that instead of having a shortage of suitable help he had on file a waiting list which enabled him to fill any vacancies on his force with selected help, although some factories near by were finding it impossible to get sufficient help.

The factory might well be regarded as a cooperative institution and the employees made to feel that its welfare is a part of their personal concern. Clean dressing rooms, clean, sanitary toilets, and simple provisions for caring for emergency accidents will be appreciated by nearly all the employees. But in order to attain such an esprit de corps the superintendent or manager himself must be foremost in planning and systematizing the work of cleaning, which must be begun at the opening of the season and tactfully enforced throughout the entire season if it is to prove successful.

### LABORATORY CONTROL.

From the standpoint of law enforcement, laboratory methods of examination are necessary, since there is no other way by which the officials on whom rests the responsibility for enforcing the law can judge correctly whether the product complies with the law's requirements. Without the check afforded by laboratory methods the product of insanitary factories would come into open competition with sound and good products, and in such condition that the consumer usually would be unable to detect its true, offensive nature.

Large manufacturers who have analysts thoroughly well-trained in microscopical methods have also found laboratory supervision of great value as a means of checking the work of their sorters and superintendents. The fact that the character of their work can be determined from an examination of the finished product is a strong incentive toward inducing employees to exercise a greater degree of care in the various details of manufacture. It is well also for the analyst to check his work from time to time with that of other reliable analysts in order to keep his own operations in agreement with those of others in the same line. No conscientious analyst would undertake to do careful analytical work for a manufacturer before he had proved himself reliable through experience with the product and through checking his findings with those of other analysts, known to be reliable.

The manufacturers also may test the ability of their analysts by submitting to them sterilized portions of the same sample at different times under different identifying marks. It is of the utmost importance, however, that the samples be exact duplicates, for if they have not been taken from the same batch after thorough mixing and then kept under sterile conditions the results are utterly worthless for purposes of comparison. It is the writer's belief that some

of our food manufacturers view this question of laboratory control from an entirely wrong angle. It is thought that there are some manufacturers who use it simply as a means of trying to get their goods to "pass inspection." Instead of seeking to make the best product possible the temptation is to make a product just good enough to escape adverse action on the part of the food-control official who examines it. It is not to be inferred from this statement that any large number of American manufacturers consciously take this attitude, but such a result is always likely to follow whenever a definite standard for a product is proposed in any line of business.

The Department of Agriculture desires to emphasize in this bulletin the supreme importance of certain methods and elementary steps in manufacturing as prerequisites in the production of sanitary goods. As the analyst for a firm once said, "If the objectionable material has been kept out during manufacture, no laboratory test will find it present when the finished product is in the bottle." If proper attention has been given to the necessary details of manufacture, no laboratory examination should be needed, while, on the other hand, if such details have been slighted, no amount of laboratory work can correct the evil and make the product one that can be classed as sanitary and worthy to be put on the market for consumption.

#### SUMMARY.

In recent years great changes have taken place in the methods of manufacturing tomato products, such as the abandonment of the "gravity system" and of storage in barrels, and the introduction of careful sorting systems.

Many manufacturers believe their plants are sanitary and do not know why their products show impurities. Examination of several factories showed defective methods of cleaning the apparatus; in other places inadequate sorting methods were found responsible for insanitary products.

The method of washing should be determined by the character of the soil in which the tomatoes are grown.

Too little attention usually is given to sorting, although it is probably the most important step in the manufacture of clean, wholesome tomato products. Only skilled, responsible workers should be intrusted with this task, and, preferably, should be worked in shifts of not over three hours. If an apron conveyor is used, the speed should be carefully regulated to the capacity of the sorters. Care should be taken to have the feed uniform. The sorting room should be lighted from the top and incandescent lighting should be provided for dark days.



Trimming and sorting should be made separate operations.

It is very difficult to make sanitary pulp from trimmings alone and its manufacture is of doubtful profit even when properly done.

It is possible to arrange a system of manufacture by which the rotten trimmings can be wholly discarded and the pulp made from good trimmings and small tomatoes.

The percentage of decay in the sorted stock should be 1 per cent or less.

Prompt handling is essential if spoilage is to be avoided.

Too much care can not be given to cleaning. Every piece of apparatus in the factory should be arranged conveniently and plenty of cleaning equipment should be available. The best results are obtained when the cleaning is highly systematized and each worker is made responsible for his part in it.

Laboratory methods of checking the character of the finished products have been found of great value.

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# UNITED STATES DEPARTMENT OF AGRICULTURE



## BULLETIN No. 570

Contribution from the Bureau of Chemistry  
CARL L. ALSBERG, Chief



Washington, D. C.



August 11, 1917

### THE BY-PRODUCTS OF RICE MILLING.<sup>1</sup>

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#### INTRODUCTION.

Most of the rice produced in the United States is grown and milled in the States of Louisiana, Texas, Arkansas, and California. A few mills also are under operation in North Carolina, South Carolina, and Georgia. Although the processes employed in rice milling are old in principle, a marked improvement has taken place in the industry during the past decade. As the industry is carried on in such a limited area of the country, however, these processes are probably unfamiliar to many people who do not live in the rice-growing sections. A description of the rice grain as it comes to the mills and of the essential steps in rice milling seems, therefore, a desirable preliminary to a discussion of rice by-products.

The three varieties of rice commonly grown in the Louisiana, Texas, and Arkansas rice districts are: Japan, Honduras, and Blue Rose. The Japan type has a short, thick grain, the Honduras type has a long kernel, while the Blue Rose type is intermediate between these two in size. The Blue Rose type, although of comparatively recent introduction, has increased rapidly in popularity because of its productiveness and milling qualities.

<sup>1</sup> This bulletin gives the results of an investigation of the rice-milling industry, conducted with special reference to the by-products obtained in the milling of rice. It should be of interest to rice millers, feed-control officials, feed manufacturers dealers, and feeders of stock.

<sup>2</sup> Acknowledgment is made to F. B. Wise, of the Bureau of Plant Industry, and A. W. Broomell, formerly of the Bureau of Chemistry, for the use of descriptive matter from U. S. Dept. Agr. Bul. 330, and to P. B. Yost and F. L. Elliot, of the New Orleans Laboratory of the Bureau of Chemistry, for assistance in the analytical work.



The rice grain as it is received at the mill from the farm thrasher is contained in a hard, siliceous hull which incloses the edible kernel. This hull is covered with small needlelike points very high in silica content. Directly beneath the hull, but separate from it and attached firmly to the endosperm or starchy body of the kernel itself, is a light-brown bran coat. The microscope reveals seven distinct layers of bran. At one end of the hulled kernel the germ or embryo is distinctly visible. The milling process normally removes the germ, six of the bran layers and a part of the seventh or aleurone layer, and leaves only the starchy part of the kernel surrounded by a portion of the last layer. The aleurone cells are very rich in protein and only about 10 per cent of the protein of the hulled rice is removed by milling. Most of the oil, however, is contained in the germ, and since all of the germ goes into the bran about 85 per cent of the oil content of the kernel is removed.

#### DESCRIPTION OF THE MILLING PROCESS.

The rice as it comes to the mill is termed "rough rice" and usually is received in sacks which ordinarily contain from 175 to 210 pounds each, the average being about 190 pounds. The trade, however, usually considers that 162 pounds constitute a "barrel." From the mill warehouse the rough rice is elevated to the top floor of the mill, where the cleaning process begins. The rough rice goes over a machine called a "scalper," which removes the sticks, stones, and other coarse material by screens and removes the dust and fine material by suction. From the scalper the rice goes to the "clipper," which removes the long beard and stems; and from the clipper to a "monitor," which by suction removes light or blighted grains of rice. The product now might be termed "cleaned rough rice," and upon this product the milling process proper is conducted.

#### MILLING MACHINERY.

*Hulling stones.*—The milling process may be divided into three parts, each of which removes a different portion of the rice and produces a distinct by-product. The first step is the removal of the hull; the second, the removal of the outer bran; and the third, the removal of the inner bran. The cleaned rough rice goes to a pair of milling stones, similar to the old-time flour-mill buhrstones. These stones, the top one of which usually revolves, are set some distance apart, so that the revolving of the stone causes the grains to assume a somewhat vertical position. In this position a pressure is exerted on the ends of the grain, which cracks or splits the hull, allowing the kernel to drop out. Care is taken to set the stones a sufficient distance apart so that there will be as little breaking of the

kernel as possible, as broken rice sells for less and is graded lower than whole rice. It is worth noting that the breaking by the stones usually is lengthwise rather than transverse. Many of the transverse breaks are already in the rice when it arrives at the mill.

*Stone reel.*—From the stones the mixture of hulled rice, unhulled rice, and hulls goes to the so-called “stone reel.” This reel is a large revolving, octagonal framework covered with wire screens, the square meshes of which are usually 14 to the linear inch. Both finer and coarser meshes are sometimes used. The fine material passing through this screen consists of broken hulls, germs, and true bran. It is termed “stone-reel bran.” The rice and hulls passing over the stone reel are conducted to a monitor which removes the loose hulls by suction.

*Paddy machine.*—The rice stream goes to the “paddy machine,” a device for separating the rough from the hulled rice. This machine consists of a large, mechanically-operated box shaker with zigzag divisions formed by vertical metallic plates. These plates, together with the shaking, aid gravity in making a separation of the lighter, unhulled grains from the heavier, hulled grains. The rough-rice grains gradually move upward from the center feed and pass over the machine into a trough, while the heavier, hulled grains are collected under the lower side. The unhulled or “paddy” grains go to a pair of auxiliary stones similar to the first stones, but set somewhat closer together. The stream from these stones reenters the main stream going to the stone reel.

*Hullers.*—The natural brown rice from the clean-rice side of the paddy machine is conducted to a set of so-called “first-break hullers.” The name “huller” applied to these machines is misleading, as their purpose is to remove the bran layers from the grain which already has been hulled. The huller consists of a grooved, tapering cylinder revolving within a concentric hollow cylinder so spaced as to rub loose a portion of the bran coat with as little breaking of the grain as possible. In outward appearance it resembles a large sausage machine.

After leaving the first set of hullers the loosened bran is separated in its passage through the first-break reel and constitutes the first-break bran. The rice goes to a second set of hullers similar to the first set, but adjusted to bring the parts more closely together, so as to remove a further portion of the bran coat. Again the stream passes through a reel which separates out the second-break bran.

*Pearling cone.*—In some mills the bran is removed more gradually and some millers believe that the breakage is reduced by the use of a machine known as a “pearling cone.” This machine consists of a frustum of a cone covered with a composition stone which is sur-

rounded by a sieve mantel of heavy iron wire. The rice is fed from the top and is rubbed thoroughly between the cone and the sieve before passing out at the bottom. The severity of the scouring may be varied by raising or lowering the cone, thus decreasing or increasing its distance from the wire screen. One or two of these pearling cones are used in addition to one or two sets of hullers. The product taken off by the pearling cone is generally known as "pearling-cone meal" and may be sold as such, although some mills make a practice of mixing this product either with their bran or polish, as demand or price may dictate.

*Brush.*—During the milling in the hullers and pearling cone the rice becomes very warm, and, hence, before further treatment it is run to large cooling bins where it is allowed to remain for several hours. A further reason for collecting the grain in bins at this point lies in the fact that a uniform flow of rice to the brush is necessary for good milling, and the brush handles rice much more rapidly than the hullers or pearling cone. It is therefore necessary to store the rice from the hullers and pearling cone until such an amount has been partly milled that a uniform feed for the brush machine is assured before it is started. From these bins the rice, which is now practically white in color, but is more or less rough and unsightly in appearance, is conveyed to the brush to remove more of the inner bran coat and to give the rice a smoother finish.

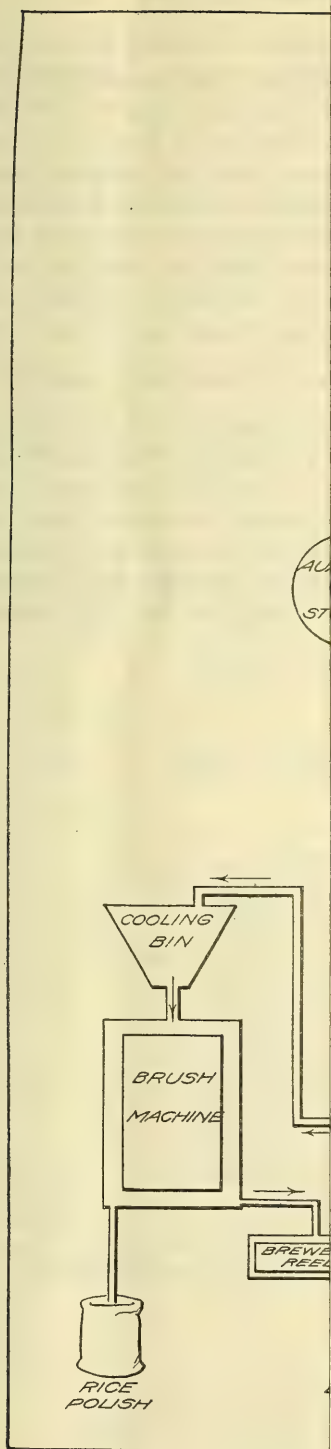
The brush consists of a vertical cylindrical frame covered with a thick padding of soft leather strips. This frame revolves at a high rate of speed within a cylinder of wire screen. The rice enters at the top of the brush and is rubbed smooth by friction with the brush and screen while passing to the bottom of the machine. A considerable amount of heat develops in the brush, and it is found necessary to cool the brush by passing a stream of air upward through it. This air current carries with it a small amount of polish which is recovered in dust collectors. The material which passes through the screen of the brush, mixed with the small amount of material from the dust collectors, constitutes the rice polish usually found on the market. The rice leaving the brush machine is suitable for market, although, as a rule, it is separated into different grades by a system of screens or graders, and in many cases is given a high finish by the use of a small amount of glucose and talc.

A graphic diagram of the mill process is shown in figure 1.

#### ANALYSIS OF RICE AND ITS BY-PRODUCTS.

With a few minor variations the process just described is followed in all rice mills. It results in three by-products, namely, rice hulls; a rice bran, consisting of a mixture of the stone-reel, first-huller, and second-huller brans; and rice polish.





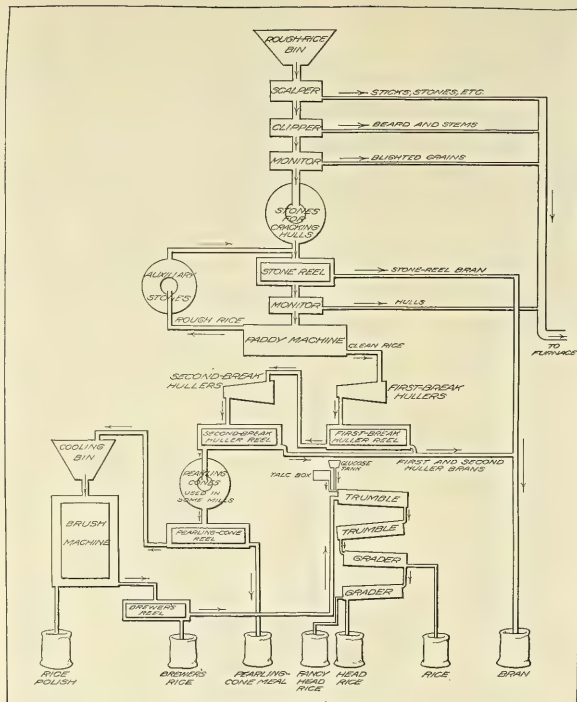


FIG. 1.—Graphic diagram of a typical rice mill.

Two general plans were followed in conducting the study of rice by-products discussed in this bulletin. A large number of mills were visited and samples of the various by-products were taken both before mixing and when ready for market. After the examination of these samples had been completed it seemed desirable to obtain more detailed information relative to the yield and character of the various products under carefully controlled and known conditions, and for this purpose special runs were made, during which each part of the reduction products was kept separate and was carefully weighed and mixed before sampling.

#### CHEMICAL COMPOSITION OF BY-PRODUCTS FROM DIFFERENT MILLS.

In reporting the chemical results on the first part of this investigation the analyses of similar products from all the mills have been grouped together in Tables 1 to 6, as follows: Rice hulls, stone-reel brans, huller brans and pearling-cone meals, mixed brans as sold by the mill, rice polishes, and miscellaneous samples of interest. In these tables each mill has been designated by a letter, so that the various products of any one mill may be followed, if desired.

TABLE 1.—*Analyses of rice hulls.*

| Mill.        | Sample No. | Moist-<br>ure. | Ash.           | Ash<br>insol-<br>uble in<br>10 per<br>cent<br>HCl. | Ratio of<br>insoluble<br>ash to<br>total ash. | Crude<br>fiber. | Protein<br>(N×<br>6.25). | Ether<br>extract. |
|--------------|------------|----------------|----------------|----------------------------------------------------|-----------------------------------------------|-----------------|--------------------------|-------------------|
|              |            | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i>                                     |                                               | <i>Per ct.</i>  | <i>Per ct.</i>           | <i>Per ct.</i>    |
| A.....       | 25062—L    | 5.47.          | 18.80          | 17.72                                              | 1 : 1.07                                      | 46.82           | 2.81                     | 0.64              |
| B.....       | 25067—L    | 6.91           | 19.12          | 18.22                                              | 1 : 1.05                                      | 44.70           | 2.50                     | 1.15              |
| C.....       | 25078—L    | 5.00           | 18.04          | 16.78                                              | 1 : 1.08                                      | 36.57           | 4.12                     | .68               |
| D.....       | 25090—L    | 7.19           | 17.31          | 16.11                                              | 1 : 1.07                                      | 46.48           | 3.16                     | 1.10              |
| E.....       | 25160—L    | 8.20           | 20.01          | 18.84                                              | 1 : 1.06                                      | 40.95           | 3.49                     | 1.22              |
| F.....       | 25165—L    | 7.76           | 21.43          | 20.67                                              | 1 : 1.04                                      | 40.96           | 2.37                     | .31               |
| G.....       | 25192—L    | 6.44           | 21.48          | 20.66                                              | 1 : 1.04                                      | 41.16           | 2.02                     | .36               |
| I.....       | 11976—L    | 7.66           | 21.13          | 20.24                                              | 1 : 1.04                                      | 40.46           | 3.68                     | 4.77              |
| J.....       | 17059—L    | 8.85           | 17.40          | 16.70                                              | 1 : 1.03                                      | 42.50           | 2.20                     | .77               |
| K.....       | 15311—K    | 9.25           | 20.59          | 19.67                                              | 1 : 1.04                                      | 39.23           | 2.94                     | .83               |
| L.....       | 12655—L    | 9.37           | 22.03          | 20.98                                              | 1 : 1.05                                      | 38.95           | 1.88                     | .73               |
| M.....       | 12643—L    | 7.88           | 20.63          | 19.88                                              | 1 : 1.03                                      | 43.01           | 2.56                     | .67               |
| N.....       | 12613—L    | 8.28           | 16.40          | 15.27                                              | 1 : 1.07                                      | 44.29           | 3.14                     | 1.31              |
| O.....       | 12622—L    | 6.31           | 20.79          | 19.97                                              | 1 : 1.04                                      | 39.84           | 1.75                     | .53               |
| P.....       | 11978—K    | 8.45           | 20.06          | 19.35                                              | 1 : 1.03                                      | 42.94           | 2.73                     | .53               |
| Q.....       | 15435—K    | 7.97           | 18.14          | 17.17                                              | 1 : 1.06                                      | 38.62           | 2.85                     | .82               |
| R.....       | 12604—L    | 9.69           | 17.24          | 16.14                                              | 1 : 1.06                                      | 41.65           | 2.64                     | 1.04              |
| S.....       | 12632—L    | 9.43           | 19.69          | 18.90                                              | 1 : 1.04                                      | 39.90           | 2.69                     | 1.17              |
| T.....       | 15451—K    | 9.38           | 20.81          | 19.90                                              | 1 : 1.05                                      | 39.39           | 2.08                     | .51               |
| U.....       | 17086—L    | 8.93           | 21.35          | 20.10                                              | 1 : 1.06                                      | 36.57           | 2.52                     | .86               |
| Maximum..... |            | 9.69           | 22.03          | 20.98                                              | .....                                         | 46.82           | 4.12                     | 1.31              |
| Minimum..... |            | 5.00           | 16.40          | 15.27                                              | .....                                         | 36.57           | 1.75                     | .51               |
| Average..... |            | 7.93           | 19.54          | 18.58                                              | 1 : 1.05                                      | 41.29           | 2.66                     | .80               |

<sup>1</sup> Omitted from summary, as the mill was old and did not make separations properly.



TABLE 2.—Analyses of stone-reel brans.

| Mill.        | Sample No.           | Moisture.      | Ash.           | Ash insoluble in 10 per cent HCl. | Ratio of insoluble ash to total ash. | Crude fiber.   | Protein (N $\times$ 6.25). | Ether extract. |
|--------------|----------------------|----------------|----------------|-----------------------------------|--------------------------------------|----------------|----------------------------|----------------|
|              |                      | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i>                    |                                      | <i>Per ct.</i> | <i>Per ct.</i>             | <i>Per ct.</i> |
| A.....       | 25053—L              | 9.31           | 15.96          | 12.16                             | 1:1.27                               | 20.40          | 10.69                      | 8.15           |
| B.....       | 25068—L              | 9.96           | 16.17          | 13.10                             | 1:1.23                               | 22.63          | 7.69                       | 7.30           |
| C.....       | 25080—L              | 6.75           | 17.61          | 14.24                             | 1:1.24                               | 23.50          | 9.81                       | 7.38           |
| D.....       | 25089—L              | 9.26           | 12.24          | 9.12                              | 1:1.34                               | 19.14          | 11.69                      | 9.09           |
| E.....       | 25157—L              | 9.93           | 13.42          | 9.44                              | 1:1.42                               | 15.83          | 12.44                      | 11.08          |
| F.....       | 25163—L              | 10.69          | 15.47          | 11.47                             | 1:1.34                               | 18.84          | 10.31                      | 7.21           |
| G.....       | 25183—L              | 10.25          | 14.58          | 11.61                             | 1:1.28                               | 22.01          | 9.22                       | 6.06           |
| H.....       | 11975—L              | 10.37          | 12.35          | 8.37                              | 1:1.47                               | 16.15          | 11.20                      | 10.00          |
| I.....       | 17061—L              | 10.43          | 13.50          | 9.70                              | 1:1.39                               | 18.26          | 10.01                      | 10.04          |
| J.....       | 15312—K              | 9.34           | 14.53          | 10.31                             | 1:1.41                               | 23.35          | 11.64                      | 8.38           |
| K.....       | 12654—L              | 10.40          | 16.06          | 12.84                             | 1:1.25                               | 18.06          | 9.41                       | 6.56           |
| L.....       | 12644—L              | 9.80           | 16.91          | 13.53                             | 1:1.25                               | 22.20          | 10.00                      | 8.73           |
| M.....       | 12612—L              | 8.07           | 14.05          | 10.15                             | 1:1.38                               | 17.19          | 10.89                      | 9.48           |
| N.....       | 12621—L              | 7.03           | 19.29          | 16.07                             | 1:1.20                               | 24.62          | 7.49                       | 6.59           |
| O.....       | 11980—K              | 8.86           | 13.22          | 7.74                              | 1:1.70                               | 9.40           | 11.19                      | 9.15           |
| P.....       | 15441—K              | 9.52           | 14.98          | 12.18                             | 1:1.20                               | 26.49          | 8.48                       | 5.15           |
| Q.....       | 12603—L              | 17.31          | 10.80          | 6.85                              | 1:1.56                               | 14.35          | 11.00                      | 7.98           |
| R.....       | <sup>1</sup> 12631—L | 10.45          | 14.74          | 12.14                             | 1:1.21                               | 18.42          | 9.78                       | 6.65           |
| S.....       | <sup>1</sup> 12664—L | 8.20           | 18.98          | 16.85                             | 1:1.13                               | 25.05          | 8.07                       | 5.78           |
| T.....       | <sup>2</sup> 15453—K | 10.95          | 4.69           | 1.21                              | 1:3.88                               | 5.63           | 14.53                      | 9.59           |
| U.....       | 17088—L              | 14.26          | 17.67          | 12.82                             | 1:1.37                               | 15.72          | 10.56                      | 9.47           |
| V.....       | 11957—L              | 14.37          | 11.60          | 6.19                              | 1:1.87                               | 15.35          | 12.86                      | 13.54          |
| Maximum..... |                      | 17.31          | 19.29          | 16.85                             | .....                                | 26.49          | 12.86                      | 13.54          |
| Minimum..... |                      | 6.75           | 10.80          | 6.19                              | .....                                | 9.40           | 7.49                       | 5.15           |
| Average..... |                      | 10.19          | 14.97          | 11.28                             | 1:1.33                               | 19.38          | 10.21                      | 8.28           |

<sup>1</sup> Samples were taken from different runs of the same mill at intervals of approximately two months.<sup>2</sup> Omitted from summary, as the figures reported on this sample are very abnormal, due to the remilling of broken rice.

TABLE 3.—Analyses of huller brans and pearling-cone meals.

| Mill.        | Sample No. | Type of rice and by-product.                                               | Moisture.             | Ash.                  | Ash insoluble in 10 per cent HCl. | Ratio of insoluble ash to total ash. | Crude fiber. | Protein (N×6.25). | Ether extract. |
|--------------|------------|----------------------------------------------------------------------------|-----------------------|-----------------------|-----------------------------------|--------------------------------------|--------------|-------------------|----------------|
| A.....       | 25056—L    | BLUE ROSE:<br>First-break huller bran.....                                 | <i>P. ct.</i><br>9.72 | <i>P. ct.</i><br>7.44 | <i>P. ct.</i><br>0.58             | 1:12.82                              | 8.42         | 16.69             | 20.00          |
| B.....       | 25069—L    | Do.....                                                                    | 8.38                  | 8.25                  | 1.24                              | 1: 6.65                              | 8.37         | 15.81             | 19.35          |
| E.....       | 25158—L    | Do. <sup>1</sup> .....                                                     | 7.98                  | 7.64                  | .90                               | 1: 8.50                              | 8.37         | 15.94             | 20.12          |
| K.....       | 15313—K    | Do.....                                                                    | 9.56                  | 9.34                  | .61                               | 1:15.31                              | 7.32         | 16.85             | 18.89          |
| M.....       | 12645—L    | Do.....                                                                    | 10.28                 | 8.67                  | 1.88                              | 1: 4.61                              | 9.36         | 14.35             | 18.91          |
| S.....       | 12665—L    | Do.....                                                                    | 9.32                  | 7.65                  | 2.99                              | 1: 2.56                              | 9.34         | 13.68             | 15.77          |
| E.....       | 25155—L    | Second-break huller bran <sup>1</sup> .....                                | 8.03                  | 8.18                  | 1.15                              | 1: 7.12                              | 7.61         | 15.06             | 16.21          |
| K.....       | 15314—K    | Do.....                                                                    | 8.78                  | 8.96                  | .87                               | 1:10.30                              | 8.31         | 18.64             | 20.61          |
| M.....       | 12646—L    | Do.....                                                                    | 10.00                 | 8.75                  | 1.28                              | 1: 6.83                              | 7.85         | 14.88             | 18.21          |
| S.....       | 12666—L    | Do.....                                                                    | 10.38                 | 6.48                  | 3.01                              | 1: 2.15                              | 6.92         | 11.37             | 10.23          |
| C.....       | 25081—L    | Mixture of first- and second-break huller brans <sup>2</sup> .....         | 8.97                  | 5.00                  | .40                               | 1:12.50                              | 4.13         | 12.00             | 10.97          |
| D.....       | 25091—L    | Do.....                                                                    | 7.62                  | 7.07                  | 1.17                              | 1: 6.05                              | 7.79         | 15.38             | 17.56          |
| J.....       | 17079—L    | Do.....                                                                    | 10.76                 | 7.20                  | 1.00                              | 1: 7.20                              | 8.66         | 15.33             | 17.94          |
| O.....       | 12623—L    | Do.....                                                                    | 7.48                  | 10.38                 | 2.63                              | 1: 3.95                              | 10.13        | 14.11             | 20.09          |
| R.....       | 12605—L    | Do. <sup>3</sup> .....                                                     | 13.28                 | 4.70                  | .53                               | 1: 8.86                              | 5.19         | 11.37             | 10.44          |
| R.....       | 12606—L    | Do. <sup>3</sup> .....                                                     | 9.96                  | 4.63                  | .49                               | 1: 9.43                              | 2.28         | 10.71             | 10.78          |
| U.....       | 17087—L    | Do.....                                                                    | 10.54                 | 8.89                  | 1.88                              | 1: 4.72                              | 8.97         | 16.09             | 19.96          |
| A.....       | 25059—L    | Pearling-cone meal.....                                                    | 6.87                  | 8.20                  | 1.04                              | 1: 7.90                              | 8.54         | 17.06             | 19.42          |
| B.....       | 25074—L    | Do.....                                                                    | 9.68                  | 7.84                  | .72                               | 1:10.90                              | 3.95         | 15.00             | 16.20          |
| D.....       | 25097—L    | Do.....                                                                    | 8.93                  | 7.56                  | .80                               | 1: 9.16                              | 5.83         | 14.56             | 18.55          |
| J.....       | 17071—L    | Pearling-cone meal (1st).....                                              | 8.99                  | 8.57                  | .55                               | 1:15.58                              | 3.10         | 14.98             | 16.38          |
| J.....       | 17073—L    | Pearling-cone meal (2d).....                                               | 9.28                  | 7.55                  | .54                               | 1:14.00                              | 3.26         | 14.06             | 16.98          |
| J.....       | 17075—L    | Pearling-cone meal (3d).....                                               | 9.31                  | 6.27                  | .55                               | 1:11.40                              | 1.41         | 13.14             | 13.61          |
| G.....       | 25189—L    | HONDURAS:<br>First-break huller bran.....                                  | 8.87                  | 8.44                  | 1.10                              | 1: 7.67                              | 7.87         | 15.25             | 17.64          |
| H.....       | 25101—L    | Do.....                                                                    | 8.80                  | 8.17                  | 1.00                              | 1: 8.17                              | 7.39         | 15.88             | 18.33          |
| I.....       | 11981—L    | Do.....                                                                    | 10.53                 | 9.52                  | 1.59                              | 1: 5.98                              | 7.72         | 13.97             | 17.21          |
| L.....       | 12657—L    | Do.....                                                                    | 10.58                 | 7.98                  | .82                               | 1: 9.73                              | 6.92         | 14.48             | 17.02          |
| Q.....       | 15442—K    | Do.....                                                                    | 8.97                  | 7.60                  | .61                               | 1:12.50                              | 8.28         | 17.67             | 18.58          |
| G.....       | 25190—L    | Second-break huller bran.....                                              | 7.44                  | 9.72                  | 1.01                              | 1: 9.63                              | 7.41         | 14.28             | 17.27          |
| H.....       | 25198—L    | Do.....                                                                    | 9.77                  | 9.75                  | .51                               | 1: 1.95                              | 8.98         | 14.56             | 18.94          |
| I.....       | 11983—L    | Do.....                                                                    | 11.05                 | 10.09                 | 2.11                              | 1: 4.78                              | 9.72         | 12.40             | 13.92          |
| L.....       | 12658—L    | Do.....                                                                    | 10.87                 | 9.76                  | .63                               | 1:15.49                              | 5.09         | 14.27             | 15.78          |
| Q.....       | 15443—K    | Do.....                                                                    | 8.77                  | 8.32                  | .61                               | 1:13.60                              | 8.52         | 17.41             | 19.88          |
| Q.....       | 15445—K    | First pearling-cone meal.....                                              | 6.83                  | 9.40                  | .60                               | 1:15.60                              | 4.09         | 16.80             | 16.10          |
| Q.....       | 15446—K    | Second pearling-cone meal.....                                             | 7.62                  | 5.83                  | .17                               | 1:34.30                              | 1.62         | 16.45             | 9.56           |
| N.....       | 12614—L    | JAPAN:<br>First-break huller bran.....                                     | 9.63                  | 7.32                  | 1.27                              | 1: 5.76                              | 10.70        | 15.01             | 18.77          |
| N.....       | 12615—L    | Second-break huller bran.....                                              | 10.36                 | 7.49                  | 1.01                              | 1: 7.41                              | 7.90         | 15.27             | 17.57          |
| V.....       | 11958—L    | Mixture of first- and second-break huller brans.....                       | 13.67                 | 8.68                  | 2.80                              | 1: 3.10                              | 9.83         | 13.50             | 14.49          |
| P.....       | 11981—K    | MIXTURES OF DIFFERENT TYPES:<br>First-break huller bran <sup>4</sup> ..... | 7.51                  | 7.91                  | 1.63                              | 1: 4.80                              | 8.62         | 14.05             | 14.95          |
| S.....       | 12633—L    | Do. <sup>5</sup> .....                                                     | 11.99                 | 8.02                  | 2.47                              | 1: 3.24                              | 8.61         | 14.00             | 15.43          |
| T.....       | 15454—K    | Do. <sup>6</sup> .....                                                     | 9.29                  | 7.42                  | 2.79                              | 1: 2.66                              | 8.50         | 13.91             | 9.70           |
| P.....       | 11982—K    | Second-break huller bran <sup>4</sup> .....                                | 9.05                  | 9.08                  | 1.21                              | 1: 7.50                              | 6.87         | 13.82             | 14.79          |
| S.....       | 12634—L    | Do. <sup>5</sup> .....                                                     | 11.05                 | 6.84                  | 3.37                              | 1: 2.03                              | 9.72         | 10.94             | 8.52           |
| T.....       | 15455—K    | Do. <sup>6</sup> .....                                                     | 8.56                  | 7.12                  | 1.72                              | 1: 4.14                              | 5.90         | 13.87             | 9.76           |
| Maximum..... |            |                                                                            | 13.67                 | 10.38                 | 3.37                              |                                      | 10.70        | 18.64             | 20.61          |
| Minimum..... |            |                                                                            | 6.83                  | 4.63                  | .17                               |                                      | 1.41         | 10.71             | 8.52           |
| Average..... |            |                                                                            | 9.45                  | 8.02                  | 1.29                              | 1: 6.22                              | 7.31         | 14.72             | 16.30          |

<sup>1</sup> Mixture of red rice with Blue Rose rice.<sup>2</sup> Direct from hullers; abnormal; omitted from summary.<sup>3</sup> Samples were obtained from poor rice that was heavily milled and are abnormal.<sup>4</sup> Mill was not operating.<sup>5</sup> Mixture of Blue Rose and Honduras.<sup>6</sup> Abnormal.

TABLE 4.—*Analyses of mixed brans as sold by the mill.*

| Mill.  | Sample No.           | Moisture.      | Ash.           | Ash-insoluble in 10 per cent HCl. | Ratio of insoluble ash to total ash. | Crude fiber.   | Protein (N×6.25). | Ether extract. |
|--------|----------------------|----------------|----------------|-----------------------------------|--------------------------------------|----------------|-------------------|----------------|
|        |                      | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i>                    |                                      | <i>Per ct.</i> | <i>Per cent.</i>  | <i>Per ct.</i> |
| A..... | <sup>1</sup> 25061—L | 7.88           | 13.08          | 8.48                              | 1:1.54                               | 17.83          | 12.06             | 11.75          |
| B..... | 25073—L              | 10.46          | 10.54          | 4.66                              | 1:2.26                               | 12.26          | 14.06             | 15.73          |
| C..... | 25077—L              | 9.11           | 13.38          | 6.44                              | 1:2.08                               | 12.96          | 13.50             | 15.71          |
| D..... | 25099—L              | 8.85           | 8.33           | 3.52                              | 1:2.37                               | 10.64          | 14.13             | 14.77          |
| E..... | 25159—L              | 9.37           | 8.59           | 2.44                              | 1:3.52                               | 9.54           | 15.44             | 17.48          |
| F..... | 25166—L              | 7.78           | 11.81          | 4.77                              | 1:2.48                               | 11.45          | 13.88             | 13.51          |
| G..... | 25191—L              | 10.62          | 10.16          | 4.10                              | 1:2.48                               | 11.20          | 13.19             | 14.48          |
| H..... | 25199—L              | 10.02          | 10.06          | 3.80                              | 1:3.04                               | 11.01          | 13.78             | 14.63          |
| I..... | 11984—L              | 10.39          | 10.57          | 4.03                              | 1:2.62                               | 10.71          | 13.23             | 14.85          |
| J..... | 17077—L              | 8.70           | 9.83           | 3.84                              | 1:2.56                               | 10.95          | 13.60             | 15.55          |
| K..... | 15315—K              | 8.59           | 10.66          | 2.90                              | 1:3.67                               | 10.81          | 16.65             | 16.75          |
| L..... | 12659—L              | 10.72          | 11.15          | 5.39                              | 1:2.07                               | 10.58          | 12.41             | 12.84          |
| M..... | 12647—L              | 9.50           | 10.62          | 4.04                              | 1:2.62                               | 11.91          | 14.26             | 17.49          |
| N..... | 12618—L              | 9.84           | 8.64           | 3.33                              | 1:2.59                               | 12.19          | 13.26             | 15.37          |
| O..... | <sup>1</sup> 12624—L | 7.84           | 12.10          | 6.42                              | 1:1.88                               | 13.95          | 11.88             | 15.50          |
| P..... | 11983—K              | 9.66           | 9.64           | 3.33                              | 1:2.80                               | 10.40          | 13.39             | 13.89          |
| Q..... | 15444—K              | 7.85           | 8.72           | 2.24                              | 1:3.90                               | 9.61           | 16.53             | 16.03          |
| R..... | <sup>2</sup> 12609—L | 10.67          | 9.60           | 4.86                              | 1:1.76                               | 11.72          | 11.37             | 12.80          |
| S..... | <sup>2</sup> 12638—L | 9.80           | 10.50          | 6.70                              | 1:1.57                               | 15.10          | 10.94             | 10.10          |
| S..... | <sup>2</sup> 12668—L | 9.23           | 10.98          | 7.51                              | 1:1.46                               | 13.90          | 10.25             | 10.82          |
| S..... | <sup>2</sup> 12669—L | 8.27           | 12.08          | 7.59                              | 1:1.59                               | 18.51          | 11.05             | 13.46          |
| S..... | <sup>2</sup> 12670—L | 8.81           | 9.92           | 5.33                              | 1:1.86                               | 11.70          | 12.40             | 13.89          |
| T..... | <sup>3</sup> 15456—K | 10.59          | 7.31           | 4.04                              | 1:1.81                               | 9.37           | 12.34             | 5.97           |
| U..... | <sup>4</sup> 15457—K | 8.60           | 7.85           | 3.94                              | 1:1.99                               | 11.07          | 13.39             | 9.74           |
| V..... | 17093—L              | 10.45          | 8.40           | 4.19                              | 1:2.00                               | 10.54          | 12.86             | 13.08          |
|        | 11959—L              | 15.00          | 9.70           | 3.85                              | 1:2.52                               | 12.60          | 12.68             | 13.40          |
|        | Maximum              | 15.00          | 13.38          | 6.44                              | -----                                | 12.96          | 16.65             | 17.49          |
|        | Minimum              | 7.78           | 7.85           | 2.24                              | -----                                | 9.54           | 11.88             | 9.74           |
|        | Average              | 9.65           | 10.03          | 3.78                              | 1:3.77                               | 11.28          | 13.79             | 14.75          |

<sup>1</sup> Omitted from summary, as ground hulls probably had been added to sample.<sup>2</sup> Omitted from summary, as mill was milling abnormal, damaged rice.<sup>3</sup> Omitted from summary, as mill was running on a mixed lot of broken rice.<sup>4</sup> Sample was taken from a lot of bran ready for the market. Exact history of bran unknown.TABLE 5.—*Analyses of rice polishes.*

| Mill.  | Sample No.           | Moisture.      | Ash.           | Ash-insoluble in 10 per cent HCl. | Ratio of insoluble ash to total ash. | Crude fiber.   | Protein (N×6.25). | Ether extract.    |
|--------|----------------------|----------------|----------------|-----------------------------------|--------------------------------------|----------------|-------------------|-------------------|
|        |                      | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i>                    |                                      | <i>Per ct.</i> | <i>Per cent.</i>  | <i>Per ct.</i>    |
| A..... | 25060—L              | 9.10           | 5.53           | 0.39                              | 1:14.19                              | 3.67           | 13.44             | 13.68             |
| B..... | 25075—L              | 11.04          | 6.02           | .53                               | 1:11.35                              | 2.69           | 13.50             | 11.67             |
| C..... | 25084—L              | 10.10          | 6.44           | .83                               | 1: 7.75                              | 2.25           | 12.25             | 10.15             |
| C..... | <sup>1</sup> 25085—L | 10.49          | 3.42           | .41                               | 1: 8.35                              | 1.89           | 10.69             | <sup>2</sup> 5.72 |
| D..... | 25097—L              | 9.44           | 4.56           | .64                               | 1: 7.13                              | 2.20           | 12.69             | 9.10              |
| E..... | 25161—L              | 10.13          | 4.25           | .32                               | 1:13.29                              | 1.76           | 12.63             | 9.13              |
| F..... | <sup>3</sup> 25172—L | 11.30          | 7.96           | 1.11                              | 1: 7.17                              | 2.45           | 14.19             | 10.73             |
| F..... | <sup>3</sup> 25171—L | 13.03          | 3.19           | .43                               | 1: 7.42                              | .94            | 12.13             | <sup>4</sup> 2.24 |
| G..... | 25178—L              | 10.57          | 4.68           | .24                               | 1:19.51                              | 1.38           | 11.06             | 8.59              |
| I..... | 11990—L              | 10.08          | 4.37           | .30                               | 1:14.56                              | .99            | 11.02             | 7.77              |
| J..... | <sup>4</sup> 17078—L | 9.88           | 3.07           | .31                               | 1: 9.90                              | .56            | 10.93             | <sup>2</sup> 5.61 |
| K..... | 15316—K              | 5.64           | 2.07           | .40                               | 1: 5.17                              | 2.29           | 9.31              | 12.02             |
| L..... | 12660—L              | 9.81           | 4.75           | .30                               | 1:15.83                              | .77            | 11.91             | 8.51              |
| M..... | 12651—L              | 9.29           | 5.46           | .54                               | 1:10.11                              | 1.73           | 15.24             | 12.34             |
| N..... | 12617—L              | 8.56           | 4.44           | .47                               | 1: 9.44                              | 2.27           | 12.55             | 12.10             |
| O..... | 12625—L              | 7.31           | 9.61           | 1.03                              | 1: 9.33                              | 2.52           | 13.52             | 17.75             |
| P..... | 11984—K              | 9.37           | 5.12           | -----                             | -----                                | 1.90           | 12.38             | 8.38              |
| R..... | <sup>6</sup> 12608—L | 9.65           | 2.43           | .42                               | 1: 5.78                              | 1.74           | 7.87              | 6.39              |
| S..... | 12635—L              | 10.22          | 5.95           | .96                               | 1: 6.20                              | 2.10           | 13.10             | 12.27             |
| T..... | <sup>6</sup> 15458—K | 7.50           | 4.42           | 1.40                              | 1: 8.16                              | 3.53           | 12.21             | 6.29              |
| U..... | 17089—L              | 8.70           | 6.40           | 1.17                              | 1: 5.47                              | 3.39           | 11.94             | 12.98             |
| V..... | 11962—L              | 6.68           | 5.81           | 1.28                              | 1: 4.54                              | 2.60           | 11.89             | 9.22              |
|        | Maximum              | 13.03          | 9.61           | 1.40                              | -----                                | 3.67           | 15.24             | 13.68             |
|        | Minimum              | 5.64           | 2.07           | .24                               | -----                                | .56            | 7.87              | 6.29              |
|        | Average              | 9.45           | 4.97           | .64                               | 1: 7.76                              | 2.07           | 12.11             | 9.75              |

<sup>1</sup> Polish from a second brush.<sup>2</sup> The figures for ether extract in these samples are not representative and were not used in obtaining minimum percentage.<sup>3</sup> These two polishes are mixed before being put upon the market.<sup>4</sup> In this mill the rice is scoured by three pearling cones before it is sent to the brush.<sup>5</sup> Low-grade rice that was heavily milled; polish abnormal.<sup>6</sup> Remilling mixed lot of broken rice; polish abnormal.



TABLE 6.—Analyses of miscellaneous samples of interest.

| Mill. | Sample No. | Description of sample.                                  | Moisture.      | Ash.           | Ash insoluble in 10 per cent HCl. | Ratio of insoluble ash to total ash. | Crude fiber.   | Protein (N×6.25). | Ether extract. |
|-------|------------|---------------------------------------------------------|----------------|----------------|-----------------------------------|--------------------------------------|----------------|-------------------|----------------|
|       |            |                                                         | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i>                    |                                      | <i>Per ct.</i> | <i>Per ct.</i>    | <i>Per ct.</i> |
| A.... | 25054—L    | Light or blighted grains from monitor.                  | 7.43           | 18.60          | 16.80                             | 1: 1.10                              | 35.70          | 5.80              | 2.80           |
| A.... | 25058—L    | Blighted grains mixed with stone-reel bran.             | 8.60           | 16.20          | 13.10                             | 1: 1.24                              | 26.70          | 8.90              | 6.60           |
| A.... | 25055—L    | Rice, Blue Rose type, from clean side of paddy machine. | 13.80          | 1.10           | .04                               | 1: 27.50                             | 0.96           | 8.60              | 2.00           |
| C.... | 25079—L    | Dust from dust collector connected with hull grinder.   | 8.40           | 29.90          | 25.50                             | 1: 1.17                              | 12.60          | 7.80              | 3.80           |
| F.... | 25176—L    | Brown rice from package as found on the market.         | 10.30          | 1.30           | .08                               | 1: 16.25                             | .80            | 7.80              | 1.90           |
| I.... | 11989—L    | Polish taken from brush machine by air blast.           | 9.49           | 7.28           | .55                               | 1: 13.23                             | 2.10           | 11.75             | 12.38          |
| J.... | 17060—L    | Light or blighted grains from monitor.                  | 10.21          | 17.40          | 15.90                             | 1: 1.09                              | 32.97          | 4.81              | 1.25           |
| K.... | 15310—K    | .....Do.....                                            | 9.28           | 16.40          | 14.47                             | 1: 1.13                              | 29.90          | 6.72              | 1.48           |
| P.... | 11979—K    | Ground and bolted rice hulls from mill.                 | 7.98           | 19.84          | 18.69                             | 1: 1.06                              | 36.72          | 3.56              | .93            |
| P.... | 13449—K    | Bran standardized with ground hull. <sup>1</sup>        | 10.89          | 10.43          | 6.04                              | 1: 1.70                              | 12.80          | 11.28             | 8.91           |
| P.... | 13452—K    | .....Do. <sup>1</sup> .....                             | 10.34          | 11.64          | 6.51                              | 1: 1.70                              | 16.03          | 11.64             | 10.38          |
| Q.... | 15438—K    | Ground and bolted rice hulls from mill.                 | 5.55           | 18.91          | 17.62                             | 1: 1.07                              | 36.01          | 3.76              | 1.10           |
| Q.... | 15433—K    | Light or blighted grains from monitor.                  | 9.26           | 13.12          | 11.54                             | 1: 1.10                              | 27.03          | 7.96              | 1.55           |
| Q.... | 15436—K    | Dust from dust collector connected with hull grinder.   | 6.40           | 27.71          | 24.89                             | 1: 1.10                              | 17.08          | 7.00              | 2.99           |
| G.... | 25183—L    | Rice, Hondurastype, from clean side of paddy machine.   | 14.80          | 1.20           | .20                               | 1: 6.00                              | .96            | 8.90              | 2.20           |
| S.... | 12636—L    | Polish taken from brush machine by air blast.           | 9.80           | 6.68           | 1.38                              | 1: 4.77                              | 2.04           | 13.16             | 13.15          |
| U.... | 17090—L    | .....Do.....                                            | 8.49           | 8.35           | .88                               | 1: 9.48                              | 3.65           | 13.69             | 18.99          |

<sup>1</sup> Shipped unlabeled as 20 per cent fat + protein.

## MILLING AND CHEMICAL RESULTS ON CONTROL SAMPLES FROM A TYPICAL MILL.

The second part of the work consisted in the collection and analysis of the several reduction products obtained under carefully controlled and known conditions. A typical rice mill of moderate size was selected and through the courtesy of the owners representatives of the department were given control of its operation. Arrangements were made to spout the various bran streams separately and to collect and weigh each portion of a given run as it was taken off. Samples were drawn from each stream and were analyzed separately. A complete feed analysis was made of the by-product samples and a moisture determination of the rice at various stages of milling. Four lots of rice were milled in this manner.

Lot A consisted of No. 1 Blue Rose type rice. This lot contained little or no red rice and was of as good grade as is ever used for milling. It cupped 42 pounds to the bushel. The regular adjustment of the stones and hullers was used in milling this rice.

The milling results on this lot are given in Table 7.

TABLE 7.—Yield of by-products and cleaned rice obtained from the milling of 13,935 pounds of No. 1 Blue Rose type rice. Lot A.

[Quantity of rice milled: 71 bags or 86 barrels of 162 pounds each; total weight, 13,935 pounds].

| Cleaned rice and by-products.     | Yield.  |           | Cleaned rice and by-products. | Yield.  |           |
|-----------------------------------|---------|-----------|-------------------------------|---------|-----------|
|                                   | Pounds. | Per cent. |                               | Pounds. | Per cent. |
| Hulls.....                        | 2,706.0 | 19.4      | Polish.....                   | 397.0   | 2.9       |
| Brans:                            |         |           | Head rice.....                | 7,900.0 | 56.6      |
| Stone reel (25.2 per cent)...     | 294.5   | 2.1       | Second-grade rice.....        | 1,130.0 | 8.1       |
| First break (33.6 per cent)...    | 391.5   | 2.8       | Brewer's rice.....            | 270.0   | 1.9       |
| Second break (41.2 per cent)..... | 481.0   | 3.4       | Chicken feed.....             | 100.0   | 0.7       |
|                                   |         |           | Waste.....                    | 265.0   | 1.9       |

The laboratory results on the samples from this run are shown in Table 8.

TABLE 8.—Chemical composition of by-products and of rice at different stages of milling No. 1 Blue Rose type rice. Lot A.

| Sample No. | Description of sample.                        | Moisture. | Ash.      | Ash insoluble in 10 per cent HCl. | Ratio of insoluble ash to total ash. | Crude fiber. |
|------------|-----------------------------------------------|-----------|-----------|-----------------------------------|--------------------------------------|--------------|
|            |                                               | Per cent. | Per cent. | Per cent.                         |                                      | Per cent.    |
| 11996—L    | Hulls.....                                    | 7.51      | 17.90     | 17.59                             | 1:1.02                               | 43.19        |
| 11993—L    | Stone-reel bran.....                          | 8.91      | 13.46     | 9.62                              | 1:1.40                               | 23.54        |
| 12675—L    | First-break bran.....                         | 9.28      | 7.43      | 1.03                              | 1:7.21                               | 9.13         |
| 12677—L    | Second-break bran.....                        | 9.91      | 7.24      | 1.19                              | 1:6.08                               | 7.83         |
|            | Calculated analysis of mixed bran.....        | 9.45      | 8.87      | 3.26                              | 1:2.71                               | 12.23        |
| 12679—L    | Rice polish.....                              | 8.87      | 7.39      | .60                               | 1:12.32                              | 1.59         |
| 11991—L    | Rough rice before milling.....                | 11.95     |           |                                   |                                      |              |
| 11992—L    | Cleaned rough rice.....                       | 11.67     |           |                                   |                                      |              |
| 11995—L    | Hulls and bran after the monitor.....         | 8.84      |           |                                   |                                      |              |
| 11997—L    | Rice after stone monitor going to paddy.....  | 12.68     |           |                                   |                                      |              |
| 11999—L    | Rice from rough side of paddy machine.....    | 11.90     |           |                                   |                                      |              |
| 11998—L    | Rice from clean side of paddy machine.....    | 12.33     |           |                                   |                                      |              |
| 12000—L    | Rice after first-break huller screen.....     | 12.55     |           |                                   |                                      |              |
| 12678—L    | Rice after brush machine.....                 | 12.30     |           |                                   |                                      |              |
| 12678—L    | Rice after brush machine (finely ground)..... | 11.07     | 0.30      | 0.01                              | 1:30.0                               | 0.37         |

| Sample No. | Description of sample.                        | Protein (N X 6.25). | Ether extract. | Nitrogen-free extract. | Pentosans. | Starch.   |
|------------|-----------------------------------------------|---------------------|----------------|------------------------|------------|-----------|
|            |                                               | Per cent.           | Per cent.      | Per cent.              | Per cent.  | Per cent. |
| 11996—L    | Hulls.....                                    | 1.93                | 0.59           | 28.88                  | 16.73      | 1.25      |
| 11993—L    | Stone-reel bran.....                          | 9.68                | 8.61           | 35.80                  | 12.95      | 7.82      |
| 12675—L    | First-break bran.....                         | 14.93               | 20.11          | 39.12                  | 7.35       | 12.63     |
| 12677—L    | Second-break bran.....                        | 14.60               | 18.68          | 41.74                  | 7.39       | 16.37     |
|            | Calculated analysis of mixed bran.....        | 13.47               | 16.62          | 39.36                  |            |           |
| 12679—L    | Rice polish.....                              | 12.79               | 16.99          | 52.37                  | 4.68       | 33.88     |
| 11991—L    | Rough rice before milling.....                |                     |                |                        |            |           |
| 11992—L    | Cleaned rough rice.....                       |                     |                |                        |            |           |
| 11995—L    | Hulls and bran after the monitor.....         |                     |                |                        |            |           |
| 11997—L    | Rice after stone monitor going to paddy.....  |                     |                |                        |            |           |
| 11999—L    | Rice from rough side of paddy machine.....    |                     |                |                        |            |           |
| 11998—L    | Rice from clean side of paddy machine.....    |                     |                |                        |            |           |
| 12000—L    | Rice after first-break huller screen.....     |                     |                |                        |            |           |
| 12678—L    | Rice after brush machine.....                 |                     |                |                        |            |           |
| 12678—L    | Rice after brush machine (finely ground)..... | 7.87                | 0.52           | 79.87                  |            |           |

Lot B consisted of No. 3 Blue Rose type rice. This lot contained considerable red rice and some cracked and over-ripe grains, and was of very ordinary quality. It cupped 43 pounds to the bushel. The stones were lowered to the usual height, the hullers set loose, and fed at regular speed. The rice was brushed with large feed on brush. The whole process was regulated throughout to preserve the grain rather than to obtain a highly milled rice.

The milling results on this lot are given in Table 9.

TABLE 9.—*Yield of by-products and cleaned rice obtained from the milling of 36,080 pounds of No. 3 Blue Rose type rice. Lot B.*

[Quantity of rice milled: 183 bags or 222.7 barrels of 162 pounds each; total weight, 36,080 pounds.]

| Cleaned rice and by-products.      | Yield.  |           | Cleaned rice and by-products. | Yield.  |           |
|------------------------------------|---------|-----------|-------------------------------|---------|-----------|
|                                    | Pounds. | Per cent. |                               | Pounds. | Per cent. |
| Hulls.....                         | 6,872   | 19.0      | Polish.....                   | 1,179   | 3.2       |
| Brans:                             |         |           | Head rice.....                | 22,000  | 60.9      |
| Stone reel (29.3 per cent.)..      | 755     | 2.1       | Brewer's rice.....            | 2,880   | 8.0       |
| First break (30.4 per cent.)..     | 727     | 2.0       | Chicken feed.....             | 150     | 0.4       |
| Second break (40.3 per cent.)..... | 1,001   | 2.7       | Waste.....                    | 516     | 1.4       |

The laboratory results on the samples from this run are shown in Table 10.

TABLE 10.—*Chemical composition of by-products and of rice at different stages of milling No. 3 Blue Rose type rice. Lot B.*

| Sample No. | Description of sample.                        | Moisture. | Ash.    | Ash insoluble in 10 per cent HCl. | Ratio of insoluble ash to total ash. | Crude fiber. | Protein (N × 6.25). | Ether extract. | Nitrogen-free extract. |
|------------|-----------------------------------------------|-----------|---------|-----------------------------------|--------------------------------------|--------------|---------------------|----------------|------------------------|
|            |                                               | Per ct.   | Per ct. | Per ct.                           | Per ct.                              | Per ct.      | Per ct.             | Per ct.        | Per ct.                |
| 18066—L    | Rice hulls.....                               | 5.87      | 20.01   | 19.76                             | 1:1.01                               | 38.72        | 2.08                | 0.47           | 32.85                  |
| 18063—L    | Stone-reel bran.....                          | 7.52      | 15.28   | 12.52                             | 1:1.22                               | 20.35        | 9.47                | 8.02           | 39.36                  |
| 18071—L    | First-break bran.....                         | 7.30      | 7.71    | 1.42                              | 1:5.43                               | 9.03         | 14.93               | 20.20          | 40.83                  |
| 18073—L    | Second-break bran.....                        | 7.25      | 7.77    | 1.34                              | 1:5.80                               | 7.72         | 14.68               | 19.51          | 43.07                  |
|            | Calculated analysis of mixed bran.....        | 7.35      | 10.04   | 4.76                              | 1:2.32                               | 11.94        | 13.17               | 16.22          | 41.29                  |
| 18075—L    | Rice polish.....                              | 6.38      | 8.01    | 0.91                              | 1:8.80                               | 4.45         | 13.48               | 19.04          | 48.64                  |
| 18061—L    | Rough rice before milling                     | 10.42     |         |                                   |                                      |              |                     |                |                        |
| 18062—L    | Cleaned rough rice.....                       | 10.91     |         |                                   |                                      |              |                     |                |                        |
| 18064—L    | Rice, bran, and hulls after stone.....        | 10.77     |         |                                   |                                      |              |                     |                |                        |
| 18065—L    | Hulls and bran from stone monitor.....        | 7.55      |         |                                   |                                      |              |                     |                |                        |
| 18067—L    | Rice from monitor going to paddy.....         | 10.93     |         |                                   |                                      |              |                     |                |                        |
| 18069—L    | Rice from rough side of paddy machine.....    | 10.57     |         |                                   |                                      |              |                     |                |                        |
| 18068—L    | Rice from clean side of paddy machine.....    | 11.13     |         |                                   |                                      |              |                     |                |                        |
| 18078—L    | Rice after first-break reel.....              | 11.90     |         |                                   |                                      |              |                     |                |                        |
| 18072—L    | Rice after second-break huller reel.....      | 10.33     |         |                                   |                                      |              |                     |                |                        |
| 18074—L    | Rice after brush machine.....                 | 11.32     |         |                                   |                                      |              |                     |                |                        |
| 18074—L    | Rice after brush machine (finely ground)..... | 10.51     | 0.46    | 0.03                              | 1:15.3                               | 0.56         | 8.03                | 0.64           | 79.80                  |



Lot C consisted of No. 4 Japan-type rice. This lot contained considerable red rice and was light and chaffy on account of immature grains. It cupped 40 pounds to the bushel. In milling this rice the stones were set lower and the hullers set very loose.

The milling results on this lot are given in Table 11.

TABLE 11.—*Yield of by-products and cleaned rice obtained from the milling of 24,380 pounds of No. 4 Japan-type rice. Lot C.*

[Quantity of rice milled: 129 bags or 150.49 barrels of 162 pounds each; total weight, 24,380 pounds.]

| Cleaned rice and by-products.     | Yield.         |                  | Cleaned rice and by-products. | Yield.         |                  |
|-----------------------------------|----------------|------------------|-------------------------------|----------------|------------------|
|                                   | <i>Pounds.</i> | <i>Per cent.</i> |                               | <i>Pounds.</i> | <i>Per cent.</i> |
| Hulls.....                        | 4,560          | 18.7             | Polish.....                   | 868            | 3.5              |
| Brans:                            |                |                  | Head rice.....                | 15,500         | 63.5             |
| Stone reel (21.0 per cent)...     | 406            | 1.6              | Brewer's rice.....            | 1,440          | 5.9              |
| First break (41.8 per cent)...    | 806            | 3.3              | Waste.....                    | 83             | 0.3              |
| Second break (37.2 per cent)..... | 717            | 2.9              |                               |                |                  |

The laboratory results on the samples from this run are shown in Table 12.

TABLE 12.—*Chemical composition of by-products and of rice at different stages of milling No. 4 Japan-type rice. Lot C.*

| Sample No. | Description of sample.                        | Moisture.      | Ash.           | Ash insoluble in 10 per cent HCl. | Ratio of insoluble ash to total ash. | Crude fiber.   | Protein (N×6.25). | Ether extract. | Nitrogen-free extract. |
|------------|-----------------------------------------------|----------------|----------------|-----------------------------------|--------------------------------------|----------------|-------------------|----------------|------------------------|
|            |                                               | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i>                    |                                      | <i>Per ct.</i> | <i>Per ct.</i>    | <i>Per ct.</i> | <i>Per ct.</i>         |
| 12886-L    | Rice hulls.....                               | 6.19           | 18.46          | 17.85                             | 1: 1.04                              | 39.98          | 2.49              | 1.08           | 31.80                  |
| 12683-L    | Stone-reel bran.....                          | 10.28          | 13.89          | 9.90                              | 1: 1.40                              | 18.09          | 9.89              | 9.87           | 37.98                  |
| 12691-L    | First-break bran.....                         | 9.56           | 9.26           | 3.82                              | 1: 2.42                              | 10.82          | 12.56             | 14.54          | 43.26                  |
| 12693-L    | Second-break bran.....                        | 9.25           | 7.02           | 1.02                              | 1: 6.88                              | 7.17           | 13.62             | 16.53          | 46.41                  |
|            | Calculated analysis of mixed bran.....        | 9.60           | 9.40           | 4.06                              | 1: 2.35                              | 10.99          | 12.39             | 14.30          | 43.32                  |
| 12695-L    | Rice polish.....                              | 8.17           | 5.93           | 0.43                              | 1:13.79                              | 2.18           | 11.67             | 12.22          | 59.83                  |
| 12680-L    | Rough rice before milling.....                | 11.99          |                |                                   |                                      |                |                   |                |                        |
| 12684-L    | Rice hulls and bran after stones.....         | 12.14          |                |                                   |                                      |                |                   |                |                        |
| 12685-L    | Hulls and bran from stone monitor.....        | 9.26           |                |                                   |                                      |                |                   |                |                        |
| 12687-L    | Rice from stone monitor.....                  | 12.14          |                |                                   |                                      |                |                   |                |                        |
| 12689-L    | Rice from rough side of paddy machine.....    | 11.51          |                |                                   |                                      |                |                   |                |                        |
| 12690-L    | Rice after first-break huller reel.....       | 12.50          |                |                                   |                                      |                |                   |                |                        |
| 12692-L    | Rice after second-break huller reel.....      | 12.47          |                |                                   |                                      |                |                   |                |                        |
| 12694-L    | Rice after brush machine.....                 | 12.38          |                |                                   |                                      |                |                   |                |                        |
| 12694-L    | Rice after brush machine (finely ground)..... | 10.57          | 0.38           | .09                               | 1: 4.22                              | 0.47           | 7.00              | 0.59           | 80.89                  |

Lot D consisted of No. 1 Honduras-type rice. This lot was slightly seedy and weather damaged. It cupped 41 pounds per bushel. In milling, the stones were raised on account of the long grain, and the hullers were set very loose, as in milling rice of the Japan type, and were fed slower.

The milling results on this lot are given in Table 13.

TABLE 13.—Yield of by-products and cleaned rice obtained from the milling of 35,970 pounds of No. 1 Honduras-type rice. Lot D.

[Quantity of rice milled: 186 bags or 222 barrels of 162 pounds each; total weight, 35,970 pounds.]

| Cleaned rice and by-products.   | Yield.  |           | Cleaned rice and by-products. | Yield.  |           |
|---------------------------------|---------|-----------|-------------------------------|---------|-----------|
|                                 | Pounds. | Per cent. |                               | Pounds. | Per cent. |
| Hulls.....                      | 7,532   | 20.9      | Head rice.....                | 15,000  | 41.7      |
| Brans:                          |         |           | Second-grade rice.....        | 5,000   | 13.9      |
| Stone reel (29.1 per cent)...   | 878     | 2.4       | Third-grade rice.....         | 2,100   | 5.8       |
| First break (34.3 per cent)...  | 1,033   | 2.8       | Brewer's rice.....            | 960     | 2.6       |
| Second break (36.6 per cent)... | 1,101   | 3.1       | Chicken feed.....             | 400     | 1.1       |
| Polish.....                     | 1,225   | 3.4       | Waste.....                    | 741     | 2.1       |

The laboratory results on the samples from this run are shown in Table 14.

TABLE 14.—Chemical composition of by-products and of rice at different stages of milling No. 1 Honduras-type rice. Lot D.

| Sample No. | Description of sample.                        | Mois-ture.    | Ash.          | Ash in-soluble in 10 per cent HCl. | Ratio of insol-uble ash to total ash. | Crude fiber.  | Pro-tein (N× 6.25). | Ether extract. | Nitro-gen-free extract. |
|------------|-----------------------------------------------|---------------|---------------|------------------------------------|---------------------------------------|---------------|---------------------|----------------|-------------------------|
|            |                                               | <i>P. ct.</i> | <i>P. ct.</i> | <i>P. ct.</i>                      |                                       | <i>P. ct.</i> | <i>P. ct.</i>       | <i>P. ct.</i>  | <i>P. ct.</i>           |
| 18051-L    | Rice hulls.....                               | 8.50          | 20.33         | 19.29                              | 1: 1.05                               | 37.24         | 2.09                | 0.50           | 31.34                   |
| 12698-L    | Stone-reel bran.....                          | 9.63          | 15.75         | 12.80                              | 1: 1.23                               | 22.14         | 9.36                | 6.51           | 36.61                   |
| 18056-L    | First-break bran.....                         | 9.77          | 7.26          | .74                                | 1: 9.81                               | 7.60          | 15.99               | 18.38          | 41.00                   |
| 18058-L    | Second-break bran.....                        | 9.55          | 6.94          | .77                                | 1: 9.01                               | 5.92          | 14.93               | 15.75          | 46.91                   |
|            | Calculated analysis of mixed bran.....        | 9.65          | 9.62          | 4.27                               | 1: 2.24                               | 11.22         | 13.67               | 13.96          | 41.88                   |
| 18060-L    | Rice polish.....                              | 7.93          | 7.05          | .52                                | 1:13.56                               | 2.19          | 13.45               | 13.48          | 55.90                   |
| 18052-L    | Rough rice before mill-ing.....               | 12.24         | .....         | .....                              | .....                                 | .....         | .....               | .....          | .....                   |
| 12697-L    | Cleaned rough rice.....                       | 11.75         | .....         | .....                              | .....                                 | .....         | .....               | .....          | .....                   |
| 12699-L    | Rice, bran, and hulls after stone.....        | 11.57         | .....         | .....                              | .....                                 | .....         | .....               | .....          | .....                   |
| 12700-L    | Hulls and bran from stone.....                | 7.73          | .....         | .....                              | .....                                 | .....         | .....               | .....          | .....                   |
| 12696-L    | Rice from monitor going to paddy.....         | 11.74         | .....         | .....                              | .....                                 | .....         | .....               | .....          | .....                   |
| 18053-L    | Rice from clean side of paddy machine.....    | 12.08         | .....         | .....                              | .....                                 | .....         | .....               | .....          | .....                   |
| 18054-L    | Rice from rough side of paddy machine.....    | 11.75         | .....         | .....                              | .....                                 | .....         | .....               | .....          | .....                   |
| 18055-L    | Rice after first-break hullers.....           | 12.60         | .....         | .....                              | .....                                 | .....         | .....               | .....          | .....                   |
| 18057-L    | Rice after second-break hullers.....          | 12.70         | .....         | .....                              | .....                                 | .....         | .....               | .....          | .....                   |
| 18059-L    | Rice after brush machine.....                 | 12.43         | .....         | .....                              | .....                                 | .....         | .....               | .....          | .....                   |
| 18059-L    | Rice after brush machine (finely ground)..... | 11.41         | .33           | .03                                | 1:11.00                               | .59           | 9.71                | .54            | 77.42                   |

## INTERPRETATION OF RESULTS.

## CONTROL PRODUCTS.

A few interesting comparisons may be made from the milling results. The percentage of hulls from a given lot of rice varied from 18.7 per cent to 20.9 per cent, the lowest figure being for lot C of Japan-type rice and the highest figure for lot D, Honduras type. The yield of useful rice by-products—that is, all the brans and the polish—varied from 10 per cent for lot B to 11.7 per cent for lot D. As lot B was very lightly milled, this variation would be expected.

The yield of finished rice of all grades varied from 64 per cent for lot D to 68.9 per cent for lot B, showing, as would be expected, that a high yield of rice corresponds to a low yield of by-products. The percentage of the bran coat taken off at the four stages varied greatly. It would seem that more satisfactory milling results might be obtained if it were possible to make the reduction at each stage more nearly uniform.

The chemical results given in Tables 8, 10, 12, and 14 show many interesting features. The moisture of the rough rice is seen to be mainly in the kernel, as the moisture of the hull in all cases was markedly less than that of the other samples. A lower moisture content was found in the several by-products than in the rice itself. This may be due in part to the interior of the kernel having a higher moisture content than the exterior portions, but probably is due mainly to the drying of the by-products by the heat developed in the milling process. This theory is supported by the fact that the polish is of lower moisture content than are the brans.

The ash in the stone-reel bran from the four lots of rice milled approximated 15 per cent, showing the presence of hulls in this bran. This also is shown markedly by the ash insoluble in hydrochloric acid, which averaged about 11 per cent, as compared with about 1 per cent for the huller brans and polish. Lot C, composed of Japan-type rice, was the only lot that showed a high insoluble ash in the first-break huller bran. This is accounted for probably by the fact that the small grains of rice of the Japan type do not separate so well in the paddy machine as do other types of rice.

A marked tendency for the ether extract to exceed protein was observed in all brans, particularly in those from Blue Rose rice, which, in general, are higher in ether extract than, and have approximately the same amount of protein as, brans from the other types of rice. The relation of ether extract to protein gives some indication as to the addition of hulls, since hulls contain considerably more protein than ether extract, and their addition to the bran tends to bring the determinations for these two constituents more closely together than would be the case if the bran were free from hulls. This has been observed in the case of so-called 20 per cent brans, which have been standardized to 20 per cent fat plus protein by the addition of hulls. The trade custom of rating rice bran on the basis of the fat plus protein content is of long standing.

The percentage of crude fiber decreased markedly as the reduction process was continued. The high figures for stone-reel bran are, of course, due to the presence of hulls. The determinations of pentosans and starch made on samples of lot A appear to furnish no information regarding the products not given by the other figures.



In the calculated analyses given in Tables 8, 10, 12, and 14, for the mixed brans as they would ordinarily appear on the market, the ash in all cases was 10 per cent or less, the insoluble ash in all cases was below 5 per cent, and the fat plus protein ranged from 26.7 per cent to nearly 30 per cent. The crude fiber was always above 10 per cent, a figure considered by many chemists to be the limit for a pure rice bran. The nitrogen-free extract approximated 40 per cent. This figure, however, seems to be of little use in determining the character of the product, except that in some cases a high figure may confirm the presence of a large amount of broken rice.

The results show that rice polish is characterized by very low acid-insoluble ash, by low crude-fiber value, and by high nitrogen-free extract. It should have a fat plus protein content above 20 per cent. The rice polish in lot D was somewhat abnormal for the reason that, on account of the light milling to which the rice had been subjected, the portion taken off in the brush machine consisted in part of the material which usually would be taken off in the second-break hullers.

#### ALL SAMPLES.

A consideration of the chemical results on all samples taken shows that all the rice hulls examined were very high in both ash and fiber and were of such low protein and fat content as to have practically no feeding value. In addition, their physical structure renders them harmful to animals if fed in too large amounts.

The stone-reel bran was uniformly much higher in total ash, acid-insoluble ash, and crude fiber, and was lower in protein and fat than were the huller brans. This was due to the presence of the hulls which entered the stone-reel bran after they had been broken up by the stones. The analysis of this by-product would indicate that usually it contains from 25 to 50 per cent of hulls. The huller brans were nearly all very low in fiber and acid-insoluble ash, showing their comparative freedom from hulls, and were high in protein and fat. Their composition would make them a very rich feeding stuff if used alone. At present, however, huller brans are not used for feeding purposes, partly for the reason that they do not keep well and partly because millers always have made a practice of including the product of the stone reel in their bran. This mixture is the bran as commonly found on the market and contains an amount of hulls from the stone-reel bran which would seem to add materially to the keeping qualities of the product, and at the same time to give a feed acceptable to the consumer. This product, when produced under known conditions that preclude the addition of ground hulls, should contain over 26 per cent fat plus protein. It should not exceed 13 per cent of crude fiber or 5 per cent of ash insoluble in hydrochloric acid.

All the chemical determinations given in the tables are of value in judging the nature of by-products of rice found on the market. The presence of rice hulls in rice bran is indicated at once by high ash, particularly insoluble ash, and by a low ratio of insoluble to total ash. Rice hulls also are indicated by a high crude-fiber content. Low figures in protein and fat may be due to an excess of hulls or to an excess of broken rice due to poor material or careless milling, but, when they are considered in connection with the figures for ash and fiber, the character of the product can be judged accurately.

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## UNITED STATES DEPARTMENT OF AGRICULTURE



## BULLETIN No. 571

Contribution from the Bureau of Entomology  
L. O. HOWARD, Chief



Washington, D. C.

PROFESSIONAL PAPER

December 15, 1917

THE PECAN LEAF CASE-BEARER.<sup>1</sup>

By JOHN B. GILL, *Entomological Assistant, Deciduous Fruit Insect Investigations.*

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## INTRODUCTION.

Because of the increasing importance of the pecan industry the Bureau of Entomology in 1913 established a field station at Monticello, Fla., for the purpose of studying pecan insects under the most advantageous conditions. The writer was placed in charge of the investigations, under the direction of Dr. A. L. Quaintance. In the spring of 1914 Mr. A. I. Fabis was detailed to assist in the work of this station. Extensive investigations, covering a period of nearly four years, have shown the value of certain repressive measures for the control of some of the more injurious pecan insects and have resulted in the compilation of considerable data on their life histories and natural enemies. One of the principal insect pests with which the pecan grower has to contend is the pecan leaf case-bearer (*Acrobasis nebulella* Riley). The present publication is intended to give the information now available concerning the life history and control of this insect.

The writer wishes to thank the various pecan growers who have rendered assistance in this work.

<sup>1</sup> *Acrobasis nebulella* Riley; order Lepidoptera, family Pyralidae.



## HISTORY.

The pecan leaf case-bearer (*Acrobasis nebulella*) was first described by Riley in 1872 (1),<sup>1</sup> under the name *Phycita* (*Acrobasis*) *nebulo* Walsh var. *nebulella*, from a single specimen reared from wild crab (*Crataegus* sp.). In 1887 Ragonot (2) described this insect as a "new species," naming it *Acrobasis palliolella*, and in the following year Hulst (3) also described it as "new to science," under the name *Acrobasis albocapitella*. In 1890, in Hulst's article on "The Phycitidae of North America" (4), *albocapitella* Hulst is listed as a synonym of *palliolella* Rag., and Riley's original description of this insect is given under the name *Mineola indiginella* Zell., var. *nebulella*. Ragonot (5), in 1893, in his "Monographie des Phycitinae et des Galleriinae," treated Riley's *nebulella* as a variety of *Acrobasis indiginella* Zell., and *Acrobasis palliolella* as a distinct species, giving *albocapitella* Hulst as a synonym. The same classification is given in Dyar's "List of North American Lepidoptera" (7), except that the species *indiginella* is placed in the genus *Mineola*. In Florida, in 1901, Gossard, then State entomologist (6), mentioned injury to pecans by *Mineola juglandis* and *Acrobasis caryae*, but the writer is of the opinion that some of this injury, if not all, should have been attributed to the pecan leaf case-bearer (*Acrobasis nebulella* Riley). In 1902 Gossard (8) again made brief mention of what was undoubtedly this species under the name "pecan bud-worm." Fiske (9), in 1902, under the caption "Notes on certain injurious insects in Georgia," gave life-history notes and suggested remedies for the pecan leaf-crumpler, which was presumably the insect discussed in this publication. The following year (1903) Chittenden (10) reported damage to pecan buds in Georgia by this species, and Herrick (11), in 1904, referring to Chittenden's report of injury in Georgia during 1902, gave notes on *Acrobasis* sp. It would appear that the life-history notes given in Herrick's article pertain to the pecan bud-moth (*Proteopteryx bolliana* Sling.) and not to the pecan leaf case-bearer. In 1905 Gossard (12), still the Florida State entomologist, gave an extended account of this insect, but unfortunately confused some of his notes and photographs on this species with those of the pecan bud-moth. In 1909 Herrick (14) published a bulletin on this species, giving remedies and incomplete life-history notes, as based on its occurrence in Texas. During the same year (1909) Dyar (13), under the caption "Notes on the species of *Acrobasis*, with descriptions of new ones," gave notes on both *A. palliolella* Rag. and *A. nebulella* Riley, stating that he "expects it will be found that *palliolella* is not more than a variety of *nebulella* Riley."

Worsham (15), in 1910, made a brief mention of this species as an important pest of pecan in Georgia, and in the following year (1911)

<sup>1</sup> Reference is made by number to "Literature cited," p. 27.

Chittenden (16) included it in his paper entitled "Insect enemies of the pecan." Gossard (17), in 1913, under the caption "Various insects affecting nut trees," gave a short account of this species and stated that errors crept into his publication (12) on insects of the pecan, with regard to the pecan case-bearer and the pecan bud-moth. The life history and habits of the pecan leaf case-bearer were given by the writer in a paper read during the meeting of the Florida State Horticultural Society in 1914.

The foregoing paragraphs include the more important references to this species in so far as the writer has been able to determine them.

### SYNONYMY.

Dr. Dyar's position on the synonymy of certain species of *Acrobasis* is defined in the following advice under date of August 4, 1914, given in answer to an inquiry of the writer:

*Palliolella* is the male, *nebulella* the female of one species I believe. The males are generally whiter over thorax and base of wings. *Nebulella* (1872)=*palliolella* (1887).

The synonymy of *Acrobasis nebulella* Riley is as follows:

*Phycita* (*Acrobasis*) *nebulosa* Walsh var. *nebulella* Riley, Fourth Ann. Rept. Ins. Mo., 1872, p. 41.

*Acrobasis palliolella* Ragonot, Diag. N. A. Phyc., 1887, p. 4.

*Acrobasis albocapitella* Hulst, Ent. Am., 1888, p. 116.

It seems advisable to note that in 1909 Dyar (13) made the following statement concerning *Acrobasis nebulella* Riley:

This name is listed as a variety of *Mineola indiginella* Zeller, but Riley's type before me is clearly an *Acrobasis* and differs from *palliolella* only in the gray color of thorax and base of forewings. *Minimella* Rag., made to replace Hulst's *nigrosignella* by Ragonot and referred to the synonymy of *caryae* Grote by Hulst, will find place here as a synonym.

### DISTRIBUTION.

The pecan leaf case-bearer is a native insect and is distributed more or less over the same territory as is its preferred hosts, the various hickories. The following records show that it is quite widely distributed throughout the United States. The distribution for *Acrobasis nebulella* Riley and *Acrobasis palliolella* Rag., along with certain notes as given by Dyar (13), is as follows:

Palatka, Fla., on pecan, issued May 27, 1903; Olustee, Fla., June, 1904; Black Jack Springs, Tex. (through Dr. Wm. Barnes); Cairo, Ga., issued June 7, 1903; Blackshear, Ga., on pecan, issued May 28, 1902 (W. R. Williams); Washington, D. C., on walnut, issued June 7, 1903 (August Busck); Chicago, Ill., July 1900 (Coll. W. B. Kearfott); Atlanta, Ga. (W. M. Scott); Kerrville, Tex., at light, May 30 to June 1, 1906 (F. C. Pratt); Blackshear, Ga., on pecan, issued June 12, 1902 (Dept. Agr. No. 8637); Rhinebeck, N. Y., July 27, 1888 (H. C. Dyar), the last a female and the reference, therefore, less certain.

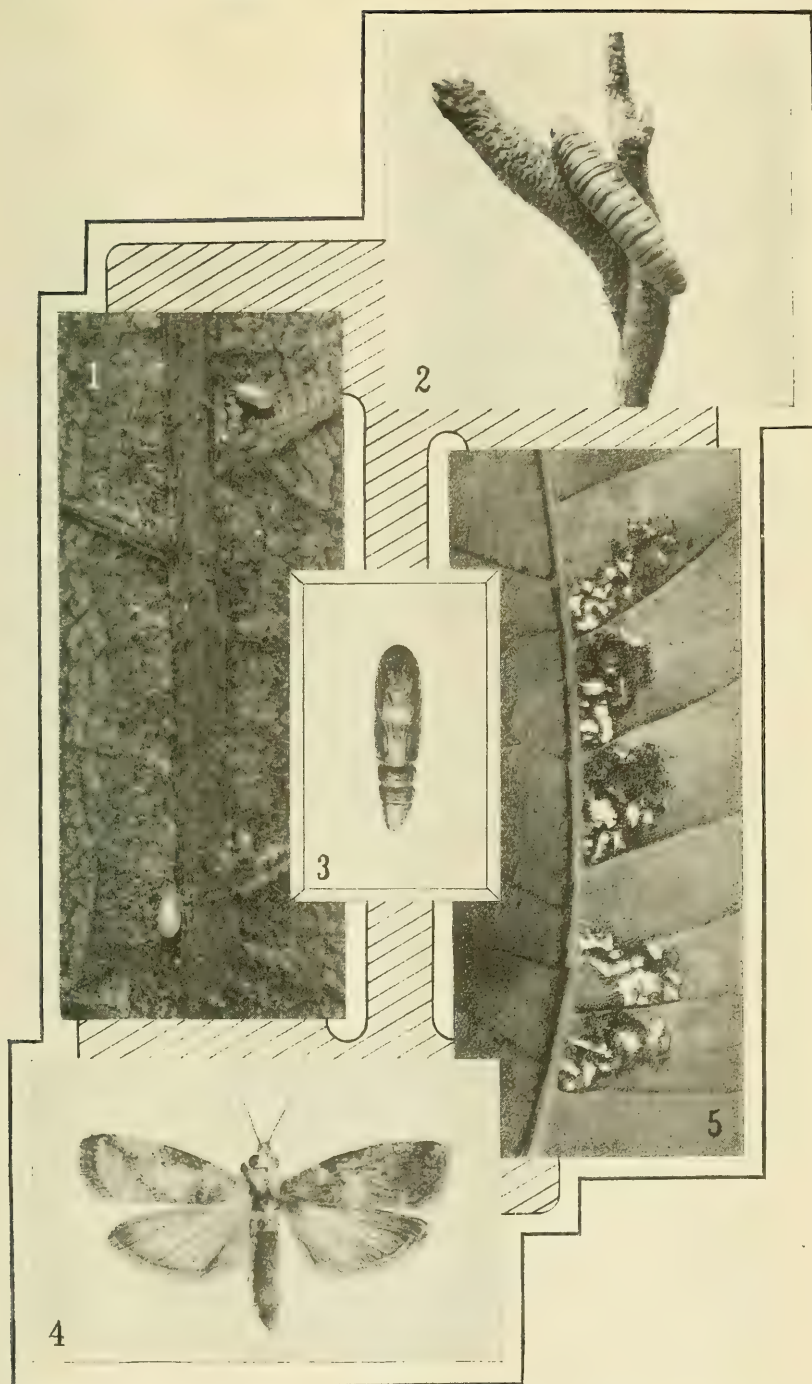
H. M. Russell reported this species as reared from pecan on May 18 and 20, 1908, at Orlando, Fla. (Chittenden No. 348), and D. K. McMillan, at one time connected with the bureau, recorded it on May 25, 1908, from pecan at Brownsville, Tex. (Chittenden No. 1045). The material on which Riley based his description was probably collected in Missouri, and the material on which Hulst (3) described this insect under the name *Acrobasis albocapitella* was taken in Canada (Ontario). Fiske (9) reported it from Georgia, Gossard (12) from Florida, and Herrick (14) from Texas (Cuero and College Station). The writer has seen it occurring in injurious numbers on pecan in Florida, Georgia, Alabama, Mississippi, Louisiana, and Texas. It has been reported to be injurious in South Carolina, and it is also known to occur in North Carolina and Virginia, but in these States apparently it does only minor damage. So far as is known, this insect ranks as a serious pest only in the southern part of the pecan-growing area, but from the foregoing records it can be seen that the species is quite widely distributed over this country.

#### FOOD PLANTS.

In his original description, Riley (1) gave wild crab (*Crataegus* sp.) as the food plant from which a single specimen was reared. Dr. Dyar (13) made the following statement: "I have 23 specimens before me, 4 bred by Dr. Riley on hickory and walnut, including the type of *nebulella*," and he also gave numerous records of its occurrence on pecan. Dr. Dyar (13) also gave a record made by Mr. August Busck in which this insect was reared from walnut on June 7, 1913, at Washington, D. C., and Mr. M. M. High (14) found it on wild hickory near College Station, Tex. Gossard (12) reared it in abundance from the pecan in Florida, and Herrick (14) states that he "reared many specimens from pecan at Cuero, Tex., where it was very abundant and doing serious damage." There are also many other records of this species occurring on pecan. So far as the writer's experience goes, the larvæ have been observed feeding upon hickory, Japanese walnut, and pecan, and moths have been reared from material collected on pecan and hickory. The writer has not yet found the black walnut to be attacked, although not infrequently that species has been found growing in close proximity to badly infested pecan trees. According to the writer's observation and experience it is very difficult to find larvæ on various species of *Hicoria* other than *H. pecan*, even in sections where this species ranks as a pest in pecan orchards. This species shows a decided preference for the pecan, and in many sections of the South it is the most injurious insect affecting the culture of this nut.

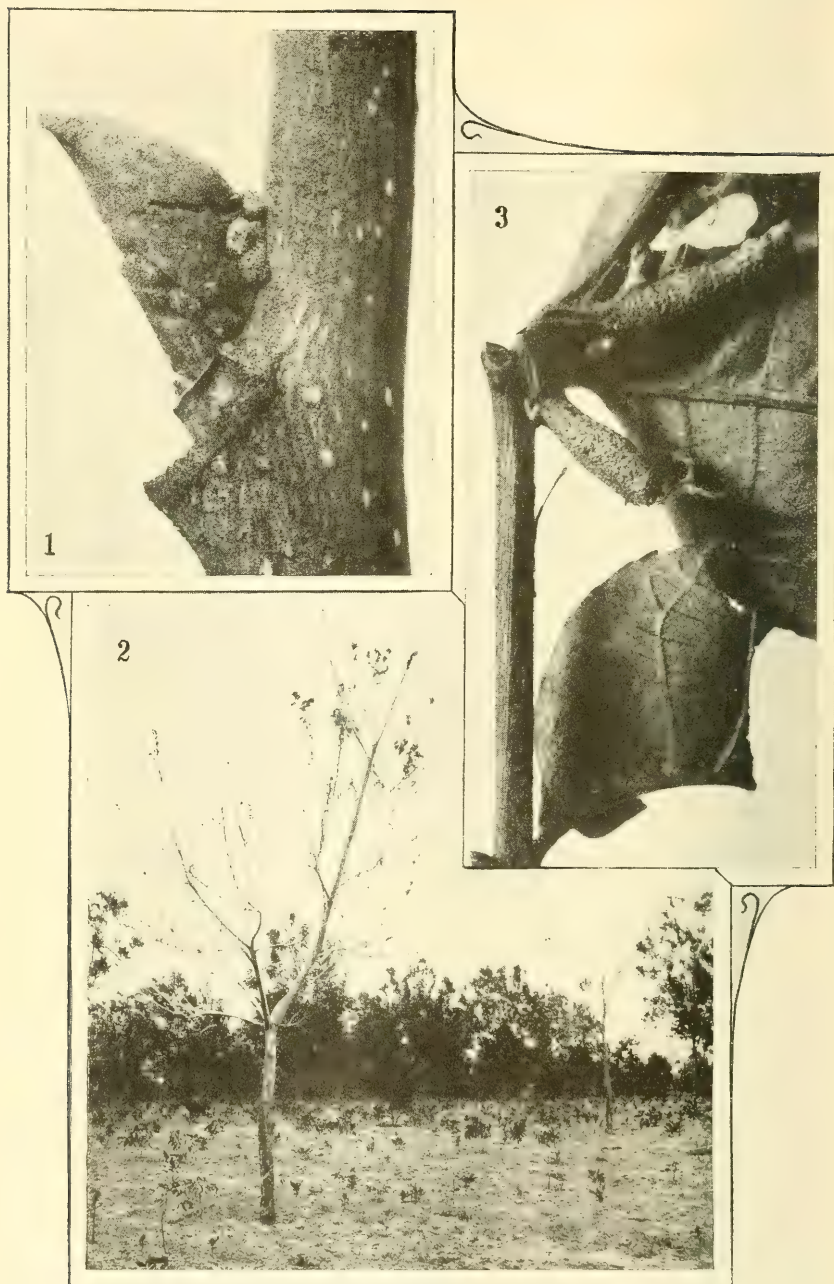
In making observations in pecan orchards in localities where this insect occurred in injurious numbers, an apparent varietal resistance





STAGES AND WORK OF THE PECAN LEAF CASE-BEARER (*ACROBASIS NEBULELLA*).

FIG. 1.—Eggs. FIG. 2.—Larva and case. FIG. 3.—Pupa. FIG. 4.—Adult, or moth. FIG. 5.—Larval cases on pecan leaflet during the summer. All enlarged. (Original.)



WORK OF THE PECAN LEAF CASE-BEARER (*ACROBASIS NEBULELLA*)

FIG. 1.—Hibernacula, or winter cases, around pecan bud. FIG. 2.—Pecan trees defoliated by larvae in the spring. FIG. 3.—Completed larval cases where pupation takes place. Figs. 1 and 3, enlarged; fig. 2, reduced. (Original.)



WORK OF THE PECAN LEAF CASE-BEARER (*ACROBASIS NEBULELLA*).

FIG. 1.—Pecan buds injured by larvæ in the spring. FIG. 2.—Larval cases on compound pecan leaf during the summer. FIG. 3.—Work of nearly matured larvæ on pecan foliage. FIG. 4.—Work of larvæ on pecan foliage at blossoming time. All slightly reduced. (Original.)





to its attacks was noticed. Such varieties as the Frotscher, Van Deman, Nelson, Pabst, Schley, Delmas, Stuart, and Success were badly infested, while the Mobile, Georgia, Havens, Teche, Waukeenah, Moore, Moneymaker, and Curtis were slightly infested. No reason can be given for this apparent varietal resistance, but it may be stated in general terms that pecan trees with very small leaves seem less likely to be heavily infested by this insect. Unfortunately, many of the best commercial varieties of pecan are subject to attacks by this pest.

#### CHARACTER OF INJURY.

The most serious damage to pecan occurs during the early spring. The larvæ feed voraciously upon the unfolding buds and leaves, as is shown in Plate III, figure 1. Just as the buds are bursting, the little overwintering "worms" gnaw their way out of their hibernacula (winter cases), which invariably are to be found snugly packed around the buds. Usually they migrate immediately to the tips of the swelling buds, upon which they partake greedily of their first meal. Upon leaving hibernation quarters some larvæ have been observed eating directly through the side of the buds, instead of entering at the tip as is usually the case. As these larvæ begin to work very early in the spring it takes but little feeding to inflict serious injury. On badly infested trees it is not uncommon to see from three to five larvæ, and sometimes more, entering a single bud. Under these conditions there is little chance for even partial development of the foliage. As the larvæ when in sufficient numbers are capable of eating the green foliage as rapidly as it appears, it is not unusual for the trees to remain defoliated for a considerable length of time. The writer has seen pecan trees kept in this condition for several weeks solely because of the attacks of this pest. On such trees the buds turn brown as a result of the feeding of the larvæ, and a block of badly infested trees takes on the appearance of blight by fire. (Pl. II, fig. 2.) When the infestation is less severe the larvæ web and tie the tender leaves together into masses, which soon become unsightly due to the wilting of the leaves and the presence of particles of excrement and larval cases with which they are united. (Pl. III, figs. 3, 4.) Late in the spring, when about half grown, the larvæ attach their cases to the leaf petioles, draw the leaflets together, and feed freely. (Pl. II, fig. 3.)

After having kept the trees in a defoliated condition for some time and, therefore, when pressed for food, these insects occasionally attack both blossom and leaf buds by burrowing directly into the ends. When thus deprived of their foliage the trees are fairly certain to become so devitalized as to be unable to make proper growth during the remainder of the season or to form fruit buds for the following season. Indirectly the trees suffer by becoming much

more susceptible to attack by certain wood-boring insects and less able to withstand drought in summer.

During the summer and early fall the larvæ, then very small and feeding but little, will be found attached to the underside of the leaflets in brownish, minute, tortuous, and winding cases (Pl. I, fig. 5; Pl. III, fig. 2), which greatly resemble at a glance brown spots such as might be caused by certain fungi. These tiny cases are enlarged only as it becomes necessary for the larvæ to build their way to new feeding areas. A detailed description of the larval cases as they appear during the summer and fall months is given on page 7. So far as the writer has observed, the injury caused to the foliage during the fall is so slight that the leaves do not fall prematurely.

### DESCRIPTION.

#### THE EGG.

The egg is elliptical in outline, somewhat convex above and flattened below. Viewed with the hand lens the surface is quite smooth, but under higher magnification it is very faintly punctate. When first deposited the egg is white with a slight greenish tinge, translucent, and iridescent in some lights. The empty shell is white. The average size of five eggs was found to be 0.55 by 0.33 mm. (0.0216 by 0.0129 inch). The eggs are deposited singly on the underside of the leaflet and usually at the junction of the veins with the midrib. Moths confined in rearing cages (battery jars) have been noticed sometimes ovipositing upon the upper surface of the leaves, but in no case has the writer observed such oviposition under natural conditions. (Pl. I, fig. 1.)

#### THE LARVA.

Upon hatching the larva is a little less than a millimeter (0.039 inch) in length. The head and prothoracic shield are brown in color, while the rest of the body is of a much lighter shade of brown. When extended the full-grown larva averages about 14.5 mm. (0.5708 inch) in length by 2.0 mm. (0.0787 inch) in greatest width. The head is round, shiny dark brown or blackish in color, and slightly rugose. The general color of the body is very dark green, except the prothoracic shield, which is somewhat lighter. The shape of the larva is nearly cylindrical, tapering slightly at both ends, but more posteriorly than anteriorly. The body is sparsely covered with fine long hairs and on either side of the dorsal surface of the second thoracic segment is a small well-defined tubercle, from the black center of which arises a fine hair. The skin, especially in the thoracic region, is quite wrinkled, there being a pair of crescentic folds on the dorsum of the second and third segments. Rudiments of these folds are evident on the other segments, but they are not prominent. The first four pairs of prolegs are quite short, only



about one-half the length of the anal pair. The pedal end of each proleg is armed with two concentric ridges of minute claws or hooks. The thoracic legs are brownish, with a tinge of olive green, and each terminates in a single claw. (Pl. I, fig. 2.)

#### THE LARVAL CASES.

• When first hatched the larva begins to feed upon the leaf surface about the egg. Soon after it constructs a brownish case out of excrementitious grains and a lining of grayish-white silken threads. The base of the summer case, as is shown in Plate I, figure 5, is invariably placed near the midrib. The case is enlarged by building away from the midrib in whatever direction the larva may chance to feed, and as the larva extends its feeding pasture in one direction and then in another the case soon assumes a very tortuous course. Throughout its entire length the case is securely attached to the under surface of the leaflet. It is composed of a rather flimsy texture of silken threads and pieces of excrement or frass, with the larger end open, and under this protection the larva extends its feeding area unnoticed. While the larva confines its attacks to the underside of the leaf, the upper surface becomes deadened and presents a brown patch, which becomes disintegrated, due to the effects of the weather. (Pl. III, fig. 2.)

In the autumn, before the foliage begins to drop, the larvæ migrate to the buds, where they construct very small, oval, brown cases (hibernacula), measuring about 1 mm. (0.039 inch) in diameter, in which they pass the winter. (Pl. II, fig. 1.) These brown cases are lined smoothly with whitish silken threads, and are covered with excrementitious particles and bits of bark and bud scales which render them rather difficult of detection upon superficial examination.

The cases of the matured larvæ as they appear in the spring are made of particles of frass, or grains of excrement, which are very closely woven together by means of fine silken threads, and are lined inside with a smooth surface of grayish-white silk. (Pl. II, fig. 2.) The finished case averages about 18 mm. (0.70 inch) in length, and is slightly enlarged in the middle. It is always attached to the petiole of the leaf by means of a foot stalk of grayish-white silk. The larva, as a rule, draws down and fastens two or more leaflets about its case, usually feeding upon the tips of these leaflets from this shelter. At first the case is rather loosely woven and slightly curved, but before the larva reaches maturity the case becomes straight with the unattached end larger than the attached one. The completed case, which is of a brownish-gray color, is so compactly constructed and tough that it can be torn only with great difficulty. Just before the larva pupates it seals the distal end of the case with a rather flimsy layer of silk.

## THE PUPA.

The pupa (Pl. I, fig. 3) is of the usual form and without conspicuous markings. When first formed it is of a dark-brown color, with a tinge of olive green, but with age it changes to deep shiny mahogany brown. The dorsal surface of the abdomen is finely punctate. The average size of five individuals was found to be 8.1 mm. (0.318 inch) by 2.26 mm. (0.088 inch). The pupa is formed within the case, and the pupal skin is not extended upon emergence of the moth.

## THE ADULT OR MOTH.

The pecan leaf case-bearer was first characterized and named in 1872 by Riley (1) as *Phycita (Acrobasis) nebulo* Walsh variety *nebulella*. The original description is as follows:

I have bred a single specimen from wild crab (*Crataegus*) which differs in some essential features from the normal form, but which nevertheless can only be considered a variety of it, as I observed no larval differences. It differs in the more uniform and subdued tone of the front wings, the markings being more suffused and indistinct; but principally in the relative narrowness of the space outside the transverse posterior line, the greater consequent width of the middle area, and smallness of the triangular brown spot—the space it occupies on the inner margin being scarcely one-half as wide as that between it and the transverse posterior line. The discal spots are also separated. Described from one good specimen.

A less technical description of the moth is as follows:

The moths measure from 14 to 18 mm. (0.55 to 0.70 inch) across the expanded wings, and they present a wide variation in color. The head, palpi, thorax, base of forewings and legs are distinctly snow-white in the specimens of males, while in the females these parts are more or less dusky gray. The abdomen is more or less white, washed with fuscous. The outer two-thirds of the forewings are gray with blackish patches, or spots, which vary to some extent. The discal spots are invariably separate and distinct. Not far from the base of the forewings is a reddish-brown stain, which is very faintly evident in some of the lighter colored forms. The hind wings are ashen gray and darker toward the outer margin. (Pl. I, fig. 4.)

## SEASONAL HISTORY AND HABITS.

The seasonal-history records were obtained at Monticello, Fla., during 1913, 1914, and 1915 in an open-air insectary, in which glass jars were used as rearing cages. In all rearing work pertaining to life-history studies pecan foliage was employed.

## THE ADULT AND EGG STAGES.

*The time of emergence.*—From material under observation during the season of 1913 it was determined that moths emerged from May 9 to July 12, inclusive. The cages, upon which the general emergence records are based, were examined daily. The dates of issuance of 269 individuals are shown in the following table:

TABLE I.—*Time of emergence of moths of the pecan leaf case-bearer during 1913 at Monticello, Fla.*

| Number of moths. | Date of emergence. | Number of moths. | Date of emergence. | Number of moths. | Date of emergence. | Number of moths. | Date of emergence. |
|------------------|--------------------|------------------|--------------------|------------------|--------------------|------------------|--------------------|
|                  | 1913.              |                  | 1913.              |                  | 1913.              |                  | 1913.              |
| 1                | May 9              | 3                | May 30             | 4                | June 14            | 7                | June 29            |
| 1                | May 11             | 3                | May 31             | 7                | June 15            | 8                | June 30            |
| 1                | May 12             | 4                | June 1             | 4                | June 16            | 4                | July 1             |
| 1                | May 13             | 5                | June 2             | 6                | June 17            | 9                | July 2             |
| 3                | May 15             | 4                | June 3             | 9                | June 18            | 2                | July 3             |
| 2                | May 16             | 1                | June 4             | 16               | June 19            | 4                | July 4             |
| 2                | May 21             | 1                | June 5             | 9                | June 20            | 4                | July 5             |
| 5                | May 22             | 6                | June 6             | 4                | June 21            | 3                | July 6             |
| 1                | May 23             | 9                | June 7             | 8                | June 22            | 2                | July 7             |
| 7                | May 24             | 10               | June 8             | 7                | June 23            | 2                | July 8             |
| 2                | May 25             | 12               | June 9             | 4                | June 24            | 2                | July 9             |
| 1                | May 26             | 2                | June 10            | 3                | June 25            | 3                | July 10            |
| 6                | May 27             | 7                | June 11            | 7                | June 26            | 4                | July 11            |
| 5                | May 28             | 3                | June 12            | 6                | June 27            | 3                | July 12            |
| 1                | May 29             | 3                | June 13            | 6                | June 28            |                  |                    |

As is shown in Table I, the time of emerging of all moths varied from May 9 to July 12. The greatest number of moths to emerge on any one day was 16, and these individuals issued on June 19. There was no marked period when the vast majority of adults came forth, as is sometimes the case with certain species. A summary of Table I shows that 45 emerged from May 9 to 31, 78 from June 1 to 15, and 104 from June 16 to 30, making in all for June a total of 182; and 42 from July 1 to 12. Most of the moths issued during the month of June, and somewhat the greater number during the latter half of the month. In pecan orchards moths were not commonly seen until the early part of June, and by the middle of July they were rarely observed; but belated individuals were met until the last days of July.

Rearing cages to determine the emergence of moths during 1914 were examined daily, except on June 7, 14, 16, 21, 28, July 5, 12, 19, 26, and August 2. The dates of issuance of 385 individuals are shown in Table II.

TABLE II.—*Time of emergence of moths of the pecan leaf case-bearer during 1914 at Monticello, Fla*

| Number of moths. | Date of emergence. | Number of moths. | Date of emergence. | Number of moths. | Date of emergence. | Number of moths. | Date of emergence. |
|------------------|--------------------|------------------|--------------------|------------------|--------------------|------------------|--------------------|
|                  | 1914.              |                  | 1914.              |                  | 1914.              |                  | 1914.              |
| 1                | May 15             | 4                | June 4             | 3                | June 22            | 8                | July 8             |
| 4                | May 18             | 2                | June 5             | 20               | June 23            | 4                | July 9             |
| 3                | May 20             | 2                | June 6             | 38               | June 24            | 5                | July 10            |
| 2                | May 21             | 3                | June 8             | 22               | June 25            | 6                | July 11            |
| 4                | May 22             | 3                | June 9             | 14               | June 26            | 1                | July 13            |
| 1                | May 23             | 5                | June 10            | 13               | June 27            | 5                | July 14            |
| 6                | May 25             | 7                | June 11            | 22               | June 29            | 4                | July 15            |
| 2                | May 27             | 7                | June 12            | 13               | June 30            | 2                | July 16            |
| 2                | May 29             | 8                | June 13            | 14               | July 1             | 5                | July 17            |
| 2                | May 30             | 13               | June 15            | 9                | July 2             | 1                | July 21            |
| 2                | May 31             | 6                | June 17            | 15               | July 3             | 4                | July 27            |
| 7                | June 1             | 2                | June 18            | 13               | July 4             | 2                | July 29            |
| 6                | June 2             | 3                | June 19            | 11               | July 6             | 2                | Aug. 4             |
| 4                | June 3             | 7                | June 20            | 5                | July 7             | 2                | Aug. 5             |



As is shown in Table II, the first moths of the season issued on May 15 and the last adults appeared on August 5, making a period of 82 days for the emergence of all individuals. The maximum emergence for a single day occurred on June 24, when 38 moths issued. A summary of Table II shows that 29 moths emerged from May 15 to 31, 238 from June 1 to 30, 114 from July 1 to 31, and 4 from August 1 to 5. Out of 238 moths to issue in June, 71 came forth during the first half of the month, while 167 emerged during June 15 to 30, which marks the period of maximum emergence. It is to be noted also that of the 114 moths issuing during July 100 emerged from July 1 to 14. So far as the records go, the last moth observed in the field was on August 1. From July 20 to the close of the month there was an extremely sudden decrease in the number of adults in the various pecan orchards in which observations were made.

During the season of 1915 rearing cages to determine the emergence of moths were examined daily, except on June 13, 15, 17, July 6, 13, 15, and 22. The dates of issuance of 591 individuals are shown in Table III.

TABLE III.—*Time of emergence of moths of the pecan leaf case-bearer during 1915 at Monticello, Fla.*

| Number of moths. | Date of emergence. | Number of moths. | Date of emergence. | Number of moths. | Date of emergence. | Number of moths. | Date of emergence. |
|------------------|--------------------|------------------|--------------------|------------------|--------------------|------------------|--------------------|
|                  | 1915.              |                  | 1915.              |                  | 1915.              |                  | 1915.              |
| 2                | May 22             | 6                | June 5             | 31               | June 21            | 6                | July 4             |
| 3                | May 24             | 20               | June 6             | 31               | June 22            | 13               | July 5             |
| 1                | May 25             | 11               | June 7             | 24               | June 23            | 22               | July 7             |
| 1                | May 26             | 5                | June 8             | 12               | June 24            | 7                | July 8             |
| 4                | May 27             | 7                | June 9             | 6                | June 25            | 6                | July 9             |
| 2                | May 28             | 8                | June 10            | 14               | June 26            | 10               | July 10            |
| 10               | May 29             | 22               | June 11            | 11               | June 27            | 13               | July 11            |
| 1                | May 30             | 22               | June 12            | 16               | June 28            | 5                | July 12            |
| 2                | May 31             | 33               | June 14            | 16               | June 29            | 10               | July 14            |
| 16               | June 1             | 12               | June 16            | 6                | June 30            | 3                | July 16            |
| 5                | June 2             | 12               | June 18            | 16               | July 1             | 1                | July 17            |
| 21               | June 3             | 16               | June 19            | 10               | July 2             | 2                | July 21            |
| 6                | June 4             | 28               | June 20            | 22               | July 3             | 2                | July 23            |

As shown in Table III, the first moth of the season issued on May 22, and the last adults appeared on July 23. A summary of Table III shows that 26 moths emerged from May 22 to 31, 417 from June 1 to 30, and 148 from July 1 to 23. Out of 417 adults issuing during June, 235 appeared from June 16 to 30, which period marks the time of maximum emergence. It should be noted also that of 148 moths emerging during July, 140 issued from July 1 to 14.

*The habits of moths in pecan orchards.*—When the moths are at rest the wings are folded rooflike on the abdomen and the head and anterior part of the body are held in a somewhat elevated position. During the day the moths prefer to frequent the weeds at the base of the trees, but they are also to be found hiding in the dense foliage of

the lower limbs. When disturbed they fly rather reluctantly from their places of concealment, but their flight is usually so rapid that it is quite difficult to follow them, although the distance traveled may be only a few feet. When alarmed, moths hiding in the débris around the base of trees often work their way into the dead leaves rather than take wing, and because of their protective color they are likely to escape detection.

*Length of life of moths.*—The average length of life for 26 adults was found to be 4.8 days, the maximum 10, and the minimum 2. Data bearing on the length of life are insufficient to give any generalization.

*Oviposition and the length of egg stage.*—It was very difficult to get reared specimens of moths to oviposit in confinement, but moths collected in pecan orchards laid eggs rather freely in some instances in rearing cages, upon both surfaces of the leaves. Under natural conditions moths oviposit only upon the underside of the leaflets. The greatest number of eggs recorded as having been deposited by a single individual was 182, which were laid by a moth collected in the field on July 20, 1916. The eggs were deposited as follows: 157 on July 21, 22 on July 22, and 3 on July 23. The records show that a period of from three to five days elapsed between the time of emergence of moths and the time of oviposition. Tables IV and V show the length of the egg stage.

TABLE IV.—*Length of egg stage of the pecan leaf case-bearer at Monticello, Fla.*

| Date moths were placed in cage. | Date of oviposition. | Date of hatching. | Length of egg stage. |
|---------------------------------|----------------------|-------------------|----------------------|
|                                 |                      |                   | <i>Days.</i>         |
| June 15, 1913                   | June 17, 1913        | June 24, 1913     | 7                    |
| Do.....                         | June 18, 1913        | June 25, 1913     | 7                    |
| Do.....                         | June 19, 1913        | .....do.....      | 6                    |
| Do.....                         | June 20, 1913        | June 26, 1913     | 6                    |
| June 30, 1914                   | July 2, 1914         | July 7, 1914      | 7                    |
| July 13, 1914                   | July 16, 1914        | July 24, 1914     | 8                    |
| Maximum.....                    |                      |                   | 8                    |
| Minimum.....                    |                      |                   | 6                    |

As shown in Table IV, the length of the egg stage was from 6 to 8 days. The moths used in obtaining these records were collected in the field, and from data on hand it is impossible to compute the average length of the egg stage. Upon emerging from the eggshell the larva feeds upon the leaf surface at the place where the egg is deposited.

TABLE V.—Length of egg stage of the pecan leaf case-bearer at Monticello, Fla., in 1915.

| Number of eggs from which larvæ emerged. | Date of oviposition. | Date of hatching. | Length of egg stage. |
|------------------------------------------|----------------------|-------------------|----------------------|
|                                          | 1915.                | 1915.             | Days.                |
| 1                                        | July 17              | July 23           | 6                    |
| 1                                        | ...do....            | July 24           | 7                    |
| 4                                        | July 18              | July 26           | 8                    |
| 18                                       | July 24              | Aug. 1            | 8                    |
| 1                                        | ...do....            | Aug. 2            | 9                    |
| 7                                        | July 31              | Aug. 6            | 6                    |
| 60                                       | ...do....            | Aug. 7            | 7                    |
| 2                                        | Aug. 4               | Aug. 11           | 7                    |
| 23                                       | Aug. 5               | Aug. 12           | 7                    |
| 1                                        | ...do....            | Aug. 13           | 8                    |
| Maximum.....                             |                      |                   | 9                    |
| Minimum.....                             |                      |                   | 6                    |
| Average for 118 individuals..            |                      |                   | 7.14+                |

It will be noted from Table V that the average length of the egg stage for 118 individuals was 7.14 days, the maximum 9, and the minimum 6.

#### THE PUPA STAGE.

Of the larvæ under observation that transformed to pupæ during 1913, the first pupated on April 20, while during 1914 and 1915 the first pupæ did not appear until May 5. During the season of 1914 the actual time of earliest pupation was, perhaps, a trifle earlier than recorded, since in cages in which only the daily emergence of moths was observed the dates of pupation were not taken, and some moths from the cages issued as early as May 15. It is very likely that some larvæ in these cages transformed to pupæ during the last few days of April.

During the year 1913 the length of the pupa stage was determined for 66 individuals, as is shown in Table VI:

TABLE VI.—Length of pupa stage of the pecan leaf case-bearer at Monticello, Fla., during 1913.

| Number of individuals. | Date of—   |             | Days as pupa. | Number of individuals. | Date of—   |             | Days as pupa. |
|------------------------|------------|-------------|---------------|------------------------|------------|-------------|---------------|
|                        | Pupa-tion. | Emer-gence. |               |                        | Pupa-tion. | Emer-gence. |               |
|                        | 1913.      | 1913.       |               |                        | 1913.      | 1913.       |               |
| 1                      | Apr. 20    | May 13      | 23            | 1                      | May 21     | June 8      | 18            |
| 2                      | Apr. 25    | May 15      | 20            | 2                      | ...do....  | June 9      | 19            |
| 1                      | ...do....  | May 16      | 21            | 3                      | ...do....  | June 11     | 21            |
| 1                      | May 2      | May 21      | 19            | 1                      | ...do....  | June 12     | 22            |
| 2                      | ...do....  | May 22      | 20            | 1                      | ...do....  | June 13     | 23            |
| 1                      | May 4      | May 24      | 20            | 2                      | May 22     | June 11     | 20            |
| 2                      | May 6      | ...do....   | 18            | 2                      | ...do....  | June 12     | 21            |
| 2                      | May 8      | May 28      | 20            | 1                      | ...do....  | June 13     | 22            |
| 1                      | May 9      | May 27      | 18            | 1                      | May 23     | June 15     | 23            |
| 1                      | ...do....  | May 31      | 22            | 2                      | May 27     | June 17     | 21            |
| 1                      | May 11     | May 30      | 19            | 2                      | May 29     | June 19     | 21            |
| 1                      | ...do....  | June 1      | 21            | 1                      | May 30     | June 20     | 21            |
| 4                      | May 12     | June 2      | 21            | 3                      | May 31     | ...do....   | 20            |
| 1                      | May 13     | ...do....   | 20            | 1                      | June 1     | June 21     | 20            |
| 3                      | May 14     | June 3      | 20            | 1                      | ...do....  | June 23     | 22            |
| 1                      | ...do....  | June 5      | 22            | 2                      | June 2     | ...do....   | 21            |
| 1                      | May 15     | June 3      | 19            |                        |            |             |               |
| 5                      | May 19     | June 7      | 19            |                        |            |             |               |
| 2                      | ...do....  | June 8      | 20            | Average.....           |            |             | 19.89         |
| 3                      | ...do....  | June 9      | 21            | Maximum.....           |            |             | 23            |
| 3                      | May 20     | June 6      | 17            | Minimum.....           |            |             | 17            |
| 1                      | ...do....  | June 8      | 19            |                        |            |             |               |





## THE LARVA STAGE.

During the season of 1913 eggs were found to hatch from about the middle of May until the last days of July, and during the season of 1914 and 1915 from the latter part of May until the first few days of August. The period over which the eggs are hatching depends, of course, upon the time of emergence of moths, and it will be noted in Tables I, II, and III that there was some variation in the issuance dates of adults during 1913, 1914, and 1915. When the young larvæ gnaw their way out of the eggshells they commence feeding upon the portion of leaflet immediately adjacent to the place where oviposition occurred. Throughout the summer and during the early fall the larvæ feed very sparingly upon the foliage, and as they extend their feeding quarters they enlarge the little winding or spiral cases which afford them protection. Although the larvæ may feed for nearly three months or even longer in some instances, they hardly attain a length greater than six one-hundredths of an inch. During the latter part of September these larvæ begin to seek hibernating quarters around the buds, where they construct small, compactly woven, oval hibernacula, and by the middle of October practically all larvæ will have left the foliage and may be found snugly protected in the hibernacula. These little "worms" very wisely abandon the compound leaves upon which they have been feeding, just a short time before the foliage begins to drop in the autumn, in order to attach the winter cases securely to the buds and twigs.

The larvæ remain in hibernation until the latter part of March or the first days of April, at which time the buds on pecan trees usually begin to open. Just as the buds are opening, the larvæ emerge from their hibernacula and attack the unfolding leaves. The pernicious feeding habits of the larvæ at this time result in serious injury to the foliage and in greatly reducing the yield of nuts. During the year 1913 the larvæ reached full growth from about April 20 until the latter part of June, but the majority pupated between May 10 and June 10. During the seasons of 1914 and 1915 the majority of the larvæ were about a week to ten days later in reaching maturity.

## NATURAL ENEMIES.

Three species of birds—the blue jay (*Cyanocitta cristata*), the mockingbird (*Mimus polyglottos*), and the orchard oriole (*Icterus spurius*)—have been observed feeding upon the larvæ of the pecan leaf case-bearer. These birds, as well perhaps as those of other species, do much to check the ravages of this pest, and their protection in the pecan orchard should be encouraged. The blue jay very likely is more beneficial than harmful to the pecan grower. In the writer's opinion the good that this bird does in feeding upon injurious pecan

insects more than offsets the injury that it is accused of doing in the fall of the year, when it may take a few nuts from the pecan trees.

The writer has reared a number of parasitic insects from the larvæ and pupæ of this case-bearer, as follows: *Itoplectis conquisitor* Say, *Triclistus apicalis* Cress., *Calliephialtes grapholithæ* (Cress.), and *Pristomerus* sp., belonging to the family Ichneumonidae; *Macrocentrus delicatus* Cress., *Meteorus* sp., *Habrobracon variabilis* Cush., and *Orgilus* sp., belonging to the family Braconidae; and *Secodella acrobasis* Cwfd., which has been described as a new species by Mr. J. C. Crawford (19), of the U. S. National Museum, and *Cerambycobius* sp., belonging to the superfamily Chalcidoidea. Two species of Tachinidae were reared from this case-bearer and were identified by Mr. W. R. Walton, of the Bureau of Entomology, as *Leskiomima tenera* Wied. and *Exorista* near *pyste* Walker. This last he considers as probably a new species. Gossard (12) reported rearing *Spilochalcis vittata* (Fab.) and *Itoplectis conquisitor* Say from this host. It is interesting to note that on one occasion specimens of *Trichogramma minutum* Riley were reared from the eggs of the pecan leaf case-bearer. Of the numerous parasites preying upon this pest, the most effective is the small chalcidoid, *Secodella acrobasis* Cwfd., which was reared in great abundance from the overwintering larvæ.

### METHODS OF CONTROL.

#### DIPPING AND SPRAYING TESTS FOR THE DESTRUCTION OF LARVÆ IN HIBERNATION.

In order to determine the effect of various spray materials on the larvæ in their hibernacula, a series of tests was made. For this work small twigs that were badly infested were selected for the treatment, which consisted in immersing the twigs in the materials used. After the treatment had been effected the twigs were kept in separate glass jars. The results of this series of experiments are shown in Table IX.

TABLE IX.—Dipping tests with sprays for destruction of hibernating larvæ of the pecan leaf case-bearer at Monticello, Fla., in 1913.

| Experiment No. | Number of twigs treated. | Material used.                              | Date of application. | Per cent-<br>age of<br>larvæ<br>emerging<br>from<br>hiber-<br>nacula. |
|----------------|--------------------------|---------------------------------------------|----------------------|-----------------------------------------------------------------------|
| I              | 25                       | Miscible oil (1:12).....                    | Feb. 11, 1913        | 18                                                                    |
| II             | 25                       | Miscible oil (1:15).....                    |                      | 15                                                                    |
| III            | 25                       | Miscible oil (1:18).....                    |                      | 20                                                                    |
| IV             | 25                       | Miscible oil (1:20).....                    |                      | 20                                                                    |
| V              | 15                       | Miscible oil (undiluted).....               |                      | 2                                                                     |
| VI             | 25                       | 10 per cent kerosene emulsion.....          |                      | 15                                                                    |
| VII            | 25                       | 20 per cent kerosene emulsion.....          |                      | 15                                                                    |
| VIII           | 25                       | Commercial lime-sulphur solution (1:8)..... |                      | 10                                                                    |
| IX             | 25                       | 40 per cent nicotine sulphate (1:32).....   |                      | 10                                                                    |
| X              | 25                       | Check; untreated.....                       |                      | 50                                                                    |



For some reason, presumably because the twigs were kept in too dry a condition, many larvæ failed to emerge from hibernacula that were not treated, as is shown in Table IX. The best results were obtained with undiluted miscible oil, while strengths ranging from 1:12 to 1:20 gave considerably less benefit for the treatment, as was also the case when 10 and 20 per cent kerosene emulsions were employed. Commercial lime-sulphur solution at 1:8 and 40 per cent nicotine sulphate at 1:32 ranked second in effectiveness.

Further dipping tests were made with commercial lime-sulphur solution on March 26, 1914. The strengths employed were 1:8 and 1:10, in which thirty heavily infested pecan twigs were dipped, and after the treatment the twigs were caged immediately in jars and placed in the out-of-doors insectary. By March 31 many of the larvæ were emerging from their hibernacula and feeding upon the developing buds. Further observations showed that lime-sulphur at these strengths was not effective in preventing many larvæ from emerging from winter quarters.

Table X shows further dipping and spraying experiments with lime-sulphur and miscible oil.

TABLE X.—*Dipping and spraying experiments for destruction of hibernating larvæ of the pecan leaf case-bearer at Monticello, Fla., in 1916.*

| Experiment No. | Treatment.                                                                 | Date of application. | Result.                                                 |
|----------------|----------------------------------------------------------------------------|----------------------|---------------------------------------------------------|
| I              | Dipped twigs in commercial lime-sulphur solution (1:8), testing 32° Baumé. | Mar. 7, 1916         | Many larvæ emerged and destroyed every bud.             |
| II             | Sprayed twigs with commercial lime-sulphur solution testing 32° Baumé.     | .....do.....         | Many larvæ emerged and destroyed most of the buds.      |
| III            | Sprayed twigs with miscible oil at 1:15.                                   | .....do.....         | Many larvæ emerged and destroyed practically every bud. |
| IV             | Check; twigs untreated.....                                                | .....do.....         | Larvæ emerged and readily destroyed every bud.          |

The twigs used in these experiments were kept in water or moist soil in order to insure the proper development of the buds. The first observations were made on April 17, 1916, and results as shown in Table X indicate the condition of the foliage. It will be noted that the lime-sulphur and miscible oil failed to destroy the larvæ.

#### SPRAYING EXPERIMENTS<sup>1</sup> FOR THE DESTRUCTION OF LARVÆ IN HIBERNATION.

A series of spraying experiments was conducted with several of the standard winter sprays to find out their effect upon larvæ in hibernation, and in all cases the material was applied thoroughly by means of a gasoline-power outfit.

<sup>1</sup> The spraying was done in bearing pecan orchards belonging to the Standard Pecan Co. and the Summit Nurseries, both of Monticello, Fla., and to Mr. Charles E. Pabst, of Ocean Spring, Miss.

The results of these experiments are as follows:

TABLE XI.—*Spraying experiments for the destruction of hibernating larvæ of the pecan leaf case-bearer at Monticello, Fla., in 1913.*

| Plat No. | Number of trees. | Treatment.                                                                              | Date of application. | Results.                                                                                                                          |
|----------|------------------|-----------------------------------------------------------------------------------------|----------------------|-----------------------------------------------------------------------------------------------------------------------------------|
| I        | 11               | Commercial lime-sulphur solution, testing 33° Baumé, at 1 gallon to 8 gallons of water. | 1913<br>Mar. 3       | 40 per cent of the larvæ emerged from hibernacula. Buds and foliage very seriously damaged by larvæ.                              |
| V        | 10               | Miscible oil at 1 gallon to 20 gallons of water.                                        | Mar. 25              | 75 per cent of the larvæ emerged from hibernacula. Buds were badly damaged by larvæ.                                              |
| VII      | 14               | Check; untreated.....                                                                   | -----                | Practically all larvæ emerged. Nearly every bud was either totally or partially destroyed. Some trees were completely defoliated. |

Neither the lime-sulphur solution nor the miscible oil gave satisfactory results, but of the two, lime-sulphur was the better. In this series of experiments a proprietary insecticide consisting of distillate oil, tobacco, and soap, and another one consisting principally of oil were tried at dormant strengths in Plats II, III, and IV, which are not included in Table XI, and both of these were found to be ineffective against the hibernating larvæ.

On February 15, 1913, in the Pabst orchard at Ocean Springs, Miss., fifteen 10-year-old trees were sprayed with commercial lime-sulphur at 1 gallon to 8 gallons of water, and on the same date six 10-year-old trees were sprayed with miscible oil at the rate of 1 gallon to 15 gallons of water. Since it was impossible for the writer to make observations on these sprayed trees because of stress of work at Monticello, Fla., Mr. Chas. E. Pabst, of Ocean Springs, Miss., was requested to report the results of these experiments. In his report he stated that there seemed to be a slight benefit derived from the lime-sulphur treatment, but so far as could be determined the miscible-oil-sprayed trees were as badly infested with larvæ as the trees that were left untreated.

In order to obtain additional information on the two most common dormant season sprays, a series of spraying experiments was conducted at Ocean Springs, Miss., and another at Monticello, Fla. The results of this work are shown in Tables XII and XIII.

TABLE XII.—*Spraying experiments for the destruction of hibernating larvæ of the pecan leaf case-bearer at Ocean Springs, Miss., in 1914.*

| Plat No. | Number of trees. | Treatment.                                                                               | Date of application. | Result.                                                                                                              |
|----------|------------------|------------------------------------------------------------------------------------------|----------------------|----------------------------------------------------------------------------------------------------------------------|
| I        | 32               | Commercial lime-sulphur solution, testing 33° Baumé, at 1 gallon to 8 gallons of water.  | 1914<br>Mar. 9       | Very slightly benefited. Sufficient number of larvæ emerged to do considerable damage to buds and foliage.           |
| II       | 17               | Commercial lime-sulphur solution, testing 33° Baumé, at 1 gallon to 10 gallons of water. | .....do.....         | Very slight benefit. A large percentage of larvæ emerged from hibernacula and severely injured the buds and foliage. |
| III      | 10               | Check; unsprayed.....                                                                    | .....                | Practically all larvæ that were not parasitized emerged from hibernacula. Buds and foliage were severely injured.    |

TABLE XIII.—*Spraying experiments for the destruction of hibernating larvæ of the pecan leaf case-bearer at Monticello, Fla., in 1914.*

| Plat No. | Number of trees. | Treatment.                                                           | Date of application. | Results.                                                                                                 |
|----------|------------------|----------------------------------------------------------------------|----------------------|----------------------------------------------------------------------------------------------------------|
| I        | 12               | Commercial lime-sulphur solution at 1 gallon to 8 gallons of water.  | Mar. 22, 1914        | Slight benefit, but a sufficient number of larvæ emerged to do much damage to buds and foliage.          |
| II       | 10               | Commercial lime-sulphur solution at 1 gallon to 10 gallons of water. | .....do.....         | Slight benefit, but many larvæ emerged from hibernacula and did considerable damage to buds and foliage. |
| III      | 8                | Miscible oil at 1 gallon to 20 gallons of water.                     | .....do.....         | Practically no benefit derived from the treatment.                                                       |

The results, as will be noted in Tables XII and XIII, show that the lime-sulphur solution at 1:8 and 1:10 gave a slight benefit, but that miscible oil was a decided failure. The number of larvæ destroyed by the lime-sulphur treatments was not sufficient to combat this pest satisfactorily. Although it has been suggested and advised by certain entomological writers that this pest can be controlled by the use of lime-sulphur during the dormant season, the results of all the experiments show conclusively that the treatment can not be depended upon as a remedy for the pecan leaf case-bearer.

#### SPRAYING EXPERIMENTS AGAINST OVERWINTERED LARVÆ.

##### EXPERIMENTS AT MONTICELLO, FLA.

The work at Monticello, Fla., was conducted in the pecan orchards of the Summit Nurseries and the Standard Pecan Co. For the spraying regular orchard gasoline-power outfits were used and the spray material was applied very thoroughly at a pressure ranging from 175 to 200 pounds. The results of the experiments are shown in Tables XIV and XV.



TABLE XIV.—*Spraying experiments against the larvæ of the pecan leaf case-bearer at Monticello, Fla., in 1913.*

| Plat No. | Number of trees. | Treatment.                                                                 | Date of application. | Results.                                                                                                       |
|----------|------------------|----------------------------------------------------------------------------|----------------------|----------------------------------------------------------------------------------------------------------------|
| VI       | 55               | Paste lead arsenate at 3 pounds plus Bordeaux mixture 4-5-50. <sup>1</sup> | Apr. 18, 1913        | Not controlled satisfactorily. About 50 per cent of the larvæ were destroyed, but the buds were badly injured. |
| VII      | 14               | Check; unsprayed.....                                                      | .....                | Most buds were infested by larvæ. Some trees were nearly defoliated.                                           |

<sup>1</sup> Bordeaux mixture was used for fungicidal purposes.

TABLE XV.—*Spraying experiments against the overwintering larvæ of the pecan leaf case-bearer at Monticello, Fla., in 1914.*

| Plat No. | Number of trees. | Treatment.                                                               | Date of application. | Results.                                                                                                                        |
|----------|------------------|--------------------------------------------------------------------------|----------------------|---------------------------------------------------------------------------------------------------------------------------------|
| IV       | 10               | Commercial lime-sulphur solution at 1 gallon to 40 gallons of water.     | Apr. 2, 1914         | Not controlled. Some few larvæ killed, but the majority continued to feed upon the buds and foliage.                            |
| V        | 10               | 40 per cent nicotine sulphate at 1 part to 700 parts of water.           | .....do.....         | Not controlled. Much damage done to the buds and foliage.                                                                       |
| VI       | 25               | Paste lead arsenate at 3 pounds to 50 gallons of water (2 applications). | Apr. 2 and 10, 1914. | Not satisfactorily controlled. Many larvæ killed, but sufficient numbers escaped to inflict serious injury to buds and foliage. |

As shown in Table XIV, a single application of paste arsenate of lead at 3 pounds to 50 gallons of Bordeaux mixture, made on April 18, 1913, failed to control the pest, although there was considerable benefit in favor of the sprayed over the check trees. Table XV shows that on trees treated with commercial lime-sulphur solution at 1:40 and 40 per cent nicotine sulphate at 1:700 on April 2, 1914, at which time the larvæ were emerging from their hibernacula, little or no benefit was derived from the treatment. Compared with the checks, the trees in Plat VI, which received two heavy applications of paste lead arsenate at 3:50 on April 2 and 10, showed that there was much in favor of the treatment, but sufficient numbers of the larvæ escaped the poison to do serious damage to the buds and foliage.

On account of the manner in which the larvæ feed upon the buds, it was found to be difficult to kill a large proportion of them before considerable damage had been done to the foliage. Results show that spraying with lead arsenate during the spring can not be relied upon as an effective remedy for this pest.

#### SPRAYING EXPERIMENTS AGAINST LARVAE IN THE SUMMER.

##### EXPERIMENTS AT MONTICELLO, FLA.

After discovering the manner in which the larvæ attack the foliage during the summer, spraying experiments were conducted to find out if the case-bearer could not be controlled practically at this stage of its life cycle. The results of this line of work are embodied in the following tables. Table XVI shows the effect of the treatment of 113 ten-year-old pecan trees in the orchard of the Summit Nurseries.

TABLE XVI.—*Spraying experiments against the larvæ of the pecan leaf case-bearer at Monticello, Fla., in 1913.*

| Plat No. | Number of trees. | Treatment.                                                                 | Date of application.  | Results.                                                                                                                                                                                                                                                                                 |
|----------|------------------|----------------------------------------------------------------------------|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| I        | 113              | One application of paste lead arsenate at 3 pounds to 50 gallons of water. | Aug. 14 and 15, 1913. | Very satisfactory control. Nearly all larvæ were killed and only a very few remained to construct hibernacula in the autumn. Was exceedingly difficult to detect any hibernacula. No appreciable amount of damage was done by the few overwintering larvæ to the buds during the spring. |
| II       | 12               | Check; untreated.....                                                      | .....                 | As many as 12 hibernacula were found around a single bud; the average was about 3 hibernacula to the bud. During the spring the larvæ appeared in numbers and seriously damaged the buds and foliage. Some trees were nearly defoliated.                                                 |

The results obtained on Plat I, as shown in Table XVI, were highly satisfactory, since most of the larvæ were killed by the arsenical application. By destroying the larvæ during the late summer or early autumn, the trees were protected from attacks during the subsequent spring, at which time very serious injuries occur to the buds and tender foliage through the peculiar manner of the feeding of overwintering larvæ. During the following spring (1914), the trees on Plat I put forth their foliage in perfect condition, but on account of the ravages of the case-bearer larvæ the unsprayed trees (Plat II) were kept in a state of partial or total defoliation for several weeks, and this condition interfered seriously with the setting of nuts. A slight arsenical injury was done to the foliage, but in no case was the damage so severe as to cause the leaves to drop.

More extensive spraying experiments were carried out with lead arsenate in 1914 than in 1913. Table XVII shows the series of experiments conducted in the Abe Simon orchard.

TABLE XVII.—*Spraying experiments against the larvæ of the pecan leaf case-bearer at Monticello, Fla., in 1914.*

| Plat No. | Number of trees. | Treatment.                                                 | Date of application.  | Result.                                                                                                                                                                            |
|----------|------------------|------------------------------------------------------------|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| I        | 22               | Powdered lead arsenate at 2 pounds to 50 gallons of water. | 1914<br>Aug. 13. .... | Practically perfect control. Scarcely any larvæ succeeded in escaping the poison to construct hibernacula. Foliage rather seriously injured by the heavy application of arsenical. |
| II       | 4                | Check; unsprayed.....                                      | .....                 | Trees were badly infested, as was determined by the great abundance of hibernacula and the prevalence of larvæ in the buds during the following spring.                            |
| III      | 18               | Paste lead arsenate at 3 pounds to 50 gallons of water.    | Aug. 14. ....         | Practically perfect control. Scarcely any larvæ succeeded in escaping the poison to construct hibernacula. Foliage rather seriously injured by the heavy application of arsenical. |

On Plats I and III the case-bearer was satisfactorily controlled, while on Plat II, which was left untreated, very serious damage was done during the spring by the overwintering larvæ. Rather serious injury was done to the foliage on Plats I and III, owing in part to the showery weather that followed the spraying, which made conditions favorable for the suspension of free arsenic on the leaves. The sprayed trees shed their foliage a little sooner than the checks, but defoliation did not take place so early as to cause the trees to bud out again.

A series of dosage tests with lead arsenate was carried out for the purpose of determining the proper strength necessary to control effectively the pest under orchard conditions. The results of this work are contained in Table XVIII.

TABLE XVIII.—*Spraying experiments against the larvæ of the pecan leaf case-bearer to determine the most effective dosage of lead arsenate; Monticello, Fla., 1914.*

| Plat No. | Number of trees. | Treatment.                                                                         | Date of application. | Results.                |                              |
|----------|------------------|------------------------------------------------------------------------------------|----------------------|-------------------------|------------------------------|
|          |                  |                                                                                    |                      | Degree of infestation.  | Arsenical injury to foliage. |
| I        | 26               | Powdered lead arsenate at 1½ pounds to 50 gallons of water.                        | 1914<br>Aug. 20      | Practically none.       | Serious.                     |
| II       | 16               | Powdered lead arsenate at 1 pound to 50 gallons of water.                          | ...do....            | ...do.....              | Rather serious.              |
| III      | 31               | Powdered lead arsenate at ½ pound to 50 gallon of water.                           | ...do....            | Light infestation.      | Slight burning.              |
| IV       | 6                | Check; unsprayed.....                                                              | ...do....            | Very heavy infestation. |                              |
| V        | 37               | Paste lead arsenate at 1 pound to 50 gallons of water.                             | ...do....            | Light infestation.      | Slight burning.              |
| VI       | 24               | Paste lead arsenate at 1½ pounds to 50 gallons of water.                           | Aug. 22              | Very light infestation. | Somewhat pronounced.         |
| VII      | 21               | Paste lead arsenate at 2 pounds to 50 gallons of water.                            | ...do....            | Practically none.       | Rather serious.              |
| VIII     | 18               | Paste lead arsenate at 2½ pounds to 50 gallons of water.                           | ...do....            | ...do.....              | Serious.                     |
| IX       | 26               | Paste lead arsenate at 3 pounds to 50 gallons of water.                            | ...do....            | ...do.....              | Do.                          |
| X        | 24               | Two pounds of paste arsenate of lead plus 4 pounds of lime to 50 gallons of water. | ...do....            | ...do.....              | Only a trace of burning.     |

As is shown in Table XVIII, the powdered lead arsenate at ½ pound (Plat III), and paste form at 1 pound (Plat V), as well as 1½ pounds (Plat VI), to 50 gallons of water were found to be too weak for effective work, while the powdered lead arsenate at 1 pound and 1½ pounds and the paste form at 2, 2½, and 3 pounds gave very satisfactory control. It was discovered that pecan foliage was quite susceptible to arsenical injury, for on all plats there was some burning. The worst burning occurred on Plats I, VIII, and IX, where the stronger dosages of lead arsenate were used; but where the weaker dosages were employed the injury was considerably lessened. The foliage on Plat X, sprayed with lead arsenate to which lime was added, was in the best condition, as only a trace of burning occurred.



Spraying experiments were conducted during the summer of 1915 for the purpose of determining the effects of various forms of lead arsenate on pecan foliage. The pecan trees selected were 12 years old and of a good size for their age. The spray material was very thoroughly applied by means of a gasoline-power outfit, using a pressure of about 200 pounds. Table XIX shows the results of this work.

TABLE XIX.—*Spraying experiments against the larvæ of the pecan leaf case-bearer at Monticello, Fla., in 1915.*

| Plat No. | Number trees. | Treatment.                                                                             | Date of application. | Results.               |                                                                                               |
|----------|---------------|----------------------------------------------------------------------------------------|----------------------|------------------------|-----------------------------------------------------------------------------------------------|
|          |               |                                                                                        |                      | Degree of infestation. | Extent of arsenical injury to foliage.                                                        |
| I        | 18            | Powdered lead arsenate 1½ pounds, plus 3 pounds of lime to 50 gallons of water.        | 1915.<br>Aug. 24     | Practically none.      | Foliage in good condition; no appreciable burning.                                            |
| II       | 18            | Powdered lead arsenate 1 pound, plus 3 pounds of lime to 50 gallons of water.          | ...do....            | ...do.....             | Do.                                                                                           |
| III      | 12            | Paste lead arsenate 3 pounds, plus 3 pounds of lime to 50 gallons of water.            | Aug. 25              | ...do.....             | Burning of foliage was rather serious.                                                        |
| IV       | 12            | Paste lead arsenate 2 pounds, plus 3 pounds of lime to 50 gallons of water.            | ...do....            | ...do.....             | Margin of leaves rather severely burned; but the trees did not shed their leaves prematurely. |
| V        | 5             | Paste triplumbic lead arsenate 2 pounds, to 50 gallons of water.                       | ...do....            | ...do.....             | Foliage rather seriously burned, especially margin of leaves.                                 |
| VI       | 7             | Paste triplumbic lead arsenate 2 pounds, plus 3 pounds of lime to 50 gallons of water. | ...do....            | ...do.....             | Foliage in good condition; no appreciable burning.                                            |

As shown in Table I, the pecan leaf case-bearer was controlled satisfactorily on all plats, but only on Plats I, II, and VI was the spraying accomplished without appreciable arsenical injury to the foliage. Maximum burning of foliage occurred on Plat V, where triplumbic arsenate of lead paste alone was used; but even in this case the injury was not severe enough to cause premature defoliation. Plats III and IV, which received 3 pounds and 2 pounds, respectively, of paste arsenate of lead plus 3 pounds of lime to each 50 gallons of water, showed rather serious arsenical injury to the margins of the leaves, while Plats I and II, which received 1½ pounds and 1 pound, respectively, of the powdered form of arsenate of lead plus 3 pounds of lime to 50 gallons of water, showed no appreciable injury to the foliage. From these observations the powdered form of lead arsenate appears less likely to cause injury to the foliage than does the paste form.

Under no circumstances was it found safe to use effective dosages of lead arsenate (triplumbic or diplumbic) in either the paste or powdered form on pecan foliage without the addition of 3 or 4 pounds of stone lime per 50 gallons of water. The work with arsenicals indi-

cates that the pecan is practically as susceptible to burning as is the peach and that the same precautions must be used in order to prevent serious injury to its foliage.

#### FUMIGATION EXPERIMENTS AGAINST HIBERNATING LARVÆ.

##### EXPERIMENTS AGAINST LARVÆ ON PECAN NURSERY TREES.

As the pecan leaf case-bearer may be freely distributed through the medium of nursery stock as larvæ in hibernacula about the buds, it was considered advisable to obtain some data in regard to fumigation. A specially constructed box, measuring 10 feet long, 3½ feet high, and 3 feet wide, was used for this work. The box was so made as to be practically air-tight. In order to test the effect of fumigation on the larvæ as well as on the plant itself, a number of infested, grafted, or budded pecan trees, ranging from 3 to 5 feet in height, were used. In order to have the trees in the best possible condition, they were dug from the nursery during the afternoon of the day before fumigation, and immediately after the fumigation experiments were completed the trees were set out in the laboratory yard at Monticello, Fla. The method and results of these experiments are shown in Table XX.

TABLE XX.—*Fumigation experiments on pecan nursery trees for destruction of overwintering larvæ of the pecan leaf case-bearer at Monticello, Fla., in 1916.*

| Experiment No. | Number of trees. | Treatment.                                                                                                            | Date of fumigation. | Results.                                                                                         |
|----------------|------------------|-----------------------------------------------------------------------------------------------------------------------|---------------------|--------------------------------------------------------------------------------------------------|
| I              | 8                | Fumigated for 1 hour with 1 ounce of sodium cyanid <sup>1</sup> per 100 cubic feet, using formula 1-2-3. <sup>2</sup> | 1916.<br>Feb. 25    | Larvæ were not killed, and these larvæ destroyed the buds. Trees were not injured by fumigation. |
| II             | 8                | Fumigated for 1 hour with 1½ ounces of sodium cyanid per 100 cubic feet, using formula 1-2-3.                         | ...do....           | All larvæ were killed. No apparent injury to trees by fumigation.                                |
| III            | 8                | Check; untreated.....                                                                                                 | .....               | Larvæ emerged in numbers and buds on the trees were badly damaged.                               |

<sup>1</sup> Sodium cyanid used was equivalent to 129 per cent potassium cyanid.

<sup>2</sup> Formula: 1 ounce (avoirdupois) sodium cyanid, 2 fluid ounces of sulphuric acid, 3 fluid ounces of water to 100 cubic feet of space.

It will be noted in Table XX that in experiment I, where 1 ounce of sodium cyanid per 100 cubic feet was used, the case-bearer larvæ were not killed, while in experiment II, where 1½ ounces of cyanid was used, the results were very satisfactory, as no larvæ emerged from the hibernacula. On May 1, 1916, it was found that the buds on trees in experiments I and III were badly damaged by the larvæ and that the buds and foliage on trees in experiment II were not injured. So far as could be determined, the fumigation had no effect whatever on the trees, as both the check and fumigated

trees made practically the same amount of growth during the course of the season.

Further fumigation experiments were conducted during March, 1916, and are reported in Table XXI. Only badly infested pecan twigs were used in these experiments, and after being fumigated, they were placed in water bottles in order to insure proper development of the buds.

TABLE XXI—*Fumigation experiments on larvæ of the pecan leaf case-bearer at Monticello, Fla., in 1916.*

| Experiment No. | Number of twigs. | Treatment.                                                                                        | Date of fumigation. | Results.                                    | Remarks.                                 |
|----------------|------------------|---------------------------------------------------------------------------------------------------|---------------------|---------------------------------------------|------------------------------------------|
| I              | 12               | Fumigated for 1 hour with $\frac{3}{4}$ ounce of sodium cyanid <sup>1</sup> per 100 cubic feet.   | 1916.<br>Mar. 4     | Larvæ emerged from hibernacula.             | All buds destroyed by larvæ.             |
| II             | 12               | Fumigated for 1 hour with $\frac{3}{4}$ ounce of sodium cyanid <sup>1</sup> per 100 cubic feet.   | Mar. 3              | do.....                                     | Nearly all buds were destroyed by larvæ. |
| III            | 12               | Fumigated for 1 hour with 1 ounce of sodium cyanid <sup>1</sup> per 100 cubic feet.               | do.....             | A number of larvæ emerged from hibernacula. | Some buds were damaged by larvæ.         |
| IV             | 12               | Fumigated for 1 hour with 1 ounce of sodium cyanid <sup>2</sup> per 100 cubic feet.               | do.....             | do.....                                     | A good many buds destroyed by larvæ.     |
| V              | 12               | Fumigated for 1 hour with $1\frac{1}{2}$ ounces of sodium cyanid <sup>1</sup> per 100 cubic feet. | do.....             | No larvæ emerged from hibernacula.          | Buds did not unfold well.                |
| VI             | 12               | Check; not fumigated.....                                                                         | do.....             | Larvæ emerged from hibernacula.             | All buds were destroyed by larvæ.        |
| VII            | 15               | Fumigated for 1 hour with $1\frac{1}{2}$ ounces of sodium cyanid <sup>1</sup> per 100 cubic feet. | Mar. 29             | No larvæ emerged from hibernacula.          | No injury to buds from fumigation.       |
| VIII           | 15               | Fumigated for 1 hour with 2 ounces of sodium cyanid <sup>1</sup> per 100 cubic feet.              | do.....             | do.....                                     | No injury to buds from fumigation.       |
| IX             | 15               | Check; not fumigated.....                                                                         | do.....             | Larvæ emerged from hibernacula.             | All buds destroyed by larvæ.             |

<sup>1</sup> Used formula 1-2-3.

<sup>2</sup> Used formula 1-1-3.

It will be noted in Table XXI that strengths of sodium cyanid of  $\frac{1}{2}$ ,  $\frac{3}{4}$ , and 1 ounce per 100 cubic feet failed to destroy the larvæ after one hour of exposure, while strengths of  $1\frac{1}{2}$  and 2 ounces per 100 cubic feet killed all larvæ. It is to be regretted that in these experiments a strength of  $1\frac{1}{4}$  ounces was not used, as it was found that while 1 ounce was not enough,  $1\frac{1}{2}$  ounces destroyed larvæ while in the winter cases. Although the maximum strength used ( $1\frac{1}{2}$  ounces per 100 cubic feet of space) is considerably in excess of that commonly employed in the fumigation of ordinary nursery stock, these experiments indicated that, while in a dormant condition, the pecan was perfectly capable of enduring the greater strength without injury.

In fumigation for the pecan leaf case-bearer materials should be used according to the following formula: 1- $1\frac{1}{2}$ -2. This means that 1 ounce (avoirdupois) of sodium cyanid,  $1\frac{1}{2}$  fluid ounces of



sulphuric acid, and 2 fluid ounces of water should be used to each 100 cubic feet of space inclosed. In purchasing sodium cyanid it is essential to obtain a high-grade product, 96 to 98 per cent pure, or, in other words, one that contains not less than 51 per cent of cyanogen. Commercial sulphuric acid, specific gravity 1.84 (66° Baumé), which is approximately 93 per cent pure, should be used for fumigation in order to obtain the best results.

#### SUMMARY.

Although the pecan leaf case-bearer is preyed upon by a number of parasitic insects and several species of birds, it was found during a course of studies extending over a period of three years that neither the parasites nor any other natural checks could be relied upon to control it, but that certain artificial measures were successful.

It was found impossible successfully to control the pecan leaf case-bearer during the dormant season, at which time the larvæ were in hibernacula around the buds. Of the various spray materials tried for the destruction of hibernating larvæ, commercial lime-sulphur solution at the strength of 1 : 8 and 1 : 10 gave the best results, but this method failed to destroy a sufficient number of the larvæ to justify its use. Tests with miscible oils at 1 : 12, 1 : 15, 1 : 18, and 1 : 20, and 10 and 20 per cent kerosene emulsions applied during the dormant season were found to be ineffective.

Because of the manner in which the larvæ feed upon the buds and foliage, the pecan leaf case-bearer in the active larva stage during the spring was not satisfactorily controlled. Spraying experiments, using a single application of arsenate of lead (paste) at 3 pounds to 50 gallons of water, 40 per cent nicotine sulphate at 1 : 700, and commercial lime-sulphur solution at 1 : 40, were tried on orchard pecan trees as the larvæ emerged from their hibernacula, at which time the buds were beginning to unfold, but none of these materials proved effective. Two applications of arsenate of lead (paste) at 3 pounds to 50 gallons of water were made on large pecan trees, the first as the larvæ emerged from their winter cases and the second eight days later. This treatment destroyed many larvæ but was not entirely effective.

Experiments in spraying with certain strengths of lead arsenate, conducted during the summer (August), gave very satisfactory results in the control of this pest, as it was discovered that the young larvæ might be destroyed readily at this stage. Based on a large series of dosage tests with lead arsenate, conducted on orchard pecan trees, it was found that no strength weaker than 1 pound of the powdered form or 2 pounds of the paste to 50 gallons of water

could be relied upon to control the case-bearer. Paste lead arsenate at 1 pound and  $1\frac{1}{2}$  pounds or the powdered form at  $\frac{1}{2}$  pound to 50 gallons of water did not give satisfactory results, but the case-bearer was controlled equally as well with 1 pound of the powder or 2 pounds of paste as with  $1\frac{1}{2}$  pounds of the powder or  $2\frac{1}{2}$  or 3 pounds of the paste to each 50 gallons of water.

In conducting extensive spraying experiments it was soon discovered that pecan foliage is more or less susceptible to arsenical burning. Experience showed that it was unsafe to spray pecan trees with lead arsenate without adding at least 3 pounds of stone lime to each 50 gallons of water.

Fumigation experiments on the hibernating larvæ on pecan twigs and pecan nursery trees demonstrated that the larvæ could be destroyed by fumigating for one hour with  $1\frac{1}{2}$  ounces of sodium cyanid per 100 cubic feet of space inclosed.

#### RECOMMENDATIONS FOR CONTROL.

Experimental work extending over a period of more than three years has shown conclusively that no matter how badly an orchard may be infested, the pecan leaf case-bearer can be controlled successfully by a single application of an arsenical solution combined with lime, if made during the latter part of summer. Experiments have shown that the best results are obtained by using 1 pound of the powdered, or 2 pounds of the paste arsenate of lead and 3 pounds of freshly slaked lime to each 50 gallons of water. Under no circumstances should arsenate of lead be used without the addition of lime, as more or less injury to the foliage and nuts is likely to follow. It is evident that spraying may be done with equal effectiveness at any time between the first of August and the middle of September. Spraying earlier than August 1 is not to be relied upon as being fully effective, since all of the eggs will not have hatched by this time, and during the course of the spraying it is considered advantageous to the work to have all larvæ feeding upon the foliage. There is also some danger in delaying the spraying in the fall, as observations have shown that some larvæ seek hibernation quarters toward the latter part of September, although the majority of them do not construct winter cases until the first week or so in October. It should be borne in mind that only the larvæ which feed on poisoned foliage are killed, and those escaping pass the winter in hibernacula around the buds and come forth in the spring to feed upon the buds and young leaves. Therefore, all who would combat successfully the pecan leaf case-bearer must realize the importance of thorough and timely spraying.

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PROFESSIONAL PAPER

October 5, 1917

## THE RECOVERY OF POTASH AS A BY-PRODUCT IN THE CEMENT INDUSTRY.

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*Scientists in Soil Laboratory Investigations.*

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### INTRODUCTION.

The present work is a continuation of an investigation that has been in progress in this laboratory for several years on the practicality of recovering potash from silicate rocks. Early in the investigation the conclusion was reached that owing to the small percentage of potash in commercial grades of any insoluble potash silicate, no process for recovering potash from such material can offer much promise of profitable application unless at the same time some product of value is recovered in addition to the potash. This principle now seems to be more or less generally recognized, and in the numerous patents that have appeared during the last two or three years on the subject of decomposing feldspar and other potash silicates specifications are given in most cases for the recovery, in addition to potash, of one or more of such various products as compounds of aluminum and of silicon, cement, raw material for the manufacture of glass or pottery, structural material, and pigment.

In a publication <sup>1</sup> prepared about five years ago, it was shown that when 1 part of feldspar and 3 parts of calcium carbonate were ignited about an hour at a temperature of 1,300–1,400°, the potash in the

<sup>1</sup> Ross, William H., Circular No. 71, Bureau of Soils; Eighth Intern. Congress of Applied Chemistry, 15, 217 (1912).

feldspar was completely volatilized and the clinker which remained was of such composition that the percentage of silica amounted to 3.2 times that of the alumina and the sum of these constituents amounted to exactly one-half the percentage of the lime present. The clinker obtained in this way, therefore, has a composition with respect to these constituents which falls within the limits required for Portland cement. It was observed also that when a quantity of calcium chloride equivalent to the alkalis in the feldspar was substituted for a part of the lime, volatilization took place in about half the time required when the ignition was made with lime alone; and that with the same mixture, on extending the time of ignition, almost complete decomposition of the feldspar could be effected at a temperature as low as 1,050°. Substitution of sodium chloride for calcium chloride gave approximately the same results.

In a later publication<sup>1</sup> it was shown that when feldspar and lime in the proper proportion to make cement are digested with water at a steam pressure of 10 to 15 atmospheres, about 90 per cent of the potash in the feldspar passes into solution in the form of the hydroxide and the residue simply requires ignition for the manufacture of Portland-cement clinker. When the proportion of lime taken is reduced much below the limit stated, only partial decomposition of the feldspar results even at increased pressures, but by adding to such a mixture a quantity of a soluble calcium salt equivalent to the alkalis in the feldspar the amount of potash recovered may then be increased considerably.

The conclusion was drawn from these experiments that potash could be set free from feldspar by substituting the latter for clay in the manufacture of cement; that the potash would be volatilized to a greater or less extent and could be recovered in the flue dust; and that it should be possible to obtain raw materials of the proper composition to yield Portland-cement clinker on ignition.

In a series of experiments recently described by Anderson and Nestell,<sup>2</sup> cement mixtures from 10 different plants in this country and Japan were ignited in a way similar to that used in the ignition of the feldspar-lime mixtures. In every respect the results corresponded to those which were obtained in this laboratory by the ignition of feldspar with lime. Thus it was found that with different cement mixtures volatilization of the potash began at about 1,100°; at 1,200° the percentage of potash volatilized in a given time was different for the different mixtures, but when the temperature was increased to 1,300°, and maintained for 1 hour, almost complete volatilization resulted in every case. When heating an hour at 1,200° the addition of 5 per cent of sodium chloride to the raw material gave an increase in volatilization of the potash from 19 per cent to 66 per cent, while the use of calcium chloride was reported to be even more

<sup>1</sup> Ross, W. H. J. Ind. Eng. Chem., 9, 467 (1917).

<sup>2</sup> J. Ind. Eng. Chem., 9, 253 (1917).



effective. The presence of sulphur dioxide in the furnace when the ignitions were made was found to have a retarding effect on the evolution of the potash.

Since potash occurs in the form of feldspar or other silicates in the raw materials used in cement manufacture, it might be inferred from the experiments made on the ignition of feldspar mixtures and of cement materials that more or less complete volatilization of the potash would take place in the burning of cement.

It happens, however, that the clinkering zone of a rotary kiln constitutes only a comparatively short portion of its length, and while the time taken for the charge to pass through the kiln may vary from about  $1\frac{1}{2}$  to  $2\frac{1}{2}$  hours, depending on the length of the kiln, the time that the charge is subjected to a clinkering temperature does not exceed one-half hour. The length of a rotary kiln must also act disadvantageously on the escape of the potash. That some potash is volatilized in cement burning has long been known, and in the case of one plant a quantitative study of the amount lost in this way has been made by R. K. Meade<sup>1</sup> from analyses of the raw material fed into the kiln, the resulting clinker, and the coal used for burning. The results of three separate tests showed that the potash volatilized ranged from 46 to 52 per cent.

#### POTASH IN RAW MATERIALS AND LOSS THROUGH VOLATILIZATION IN CEMENT MANUFACTURE.

With a view to securing more extended information in this direction, an investigation was undertaken about five years ago to ascertain the percentage of potash occurring in the raw materials used in the different cement plants of this country and also the percentage of the total potash that is volatilized in each case. Representative samples of raw mix and ground clinker were collected from the different cement plants in the United States and in Canada, with a view to analyzing each sample for potash. With the data thus obtained, and knowing the ratio between the raw mix and the cement produced, and the output of the latter, it was thought possible to calculate for each plant the approximate quantity of potash that escapes daily from the kilns. After the work was partly completed it had to be abandoned for a time. A few months ago the problem was taken up again and entirely new samples were collected. The work now has been completed, with the results given in Table I.

This table shows that the potash occurring in the raw mix used by the different cement plants in this country varies from 0.20 to 1.16 per cent. The raw materials used in the mills of the Universal Portland Cement Co. consisting of blast-furnace slag and a high-grade limestone contain considerably less potash than the average for the other cement plants of the country.

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<sup>1</sup> Chem. Engineer, 2, 221 (1905).

TABLE 1.—Content of potash in raw materials and loss through volatilization in cement manufacture.

| State and company.                         | Location of plant. | Daily output. <sup>a</sup> | Raw mix required per barrel of cement. <sup>b</sup> | Potash in— |           | Potash in daily run of— |         | Proportion of total potash lost. | Potash lost per barrel of cement. | Estimated potash in flue dust. |
|--------------------------------------------|--------------------|----------------------------|-----------------------------------------------------|------------|-----------|-------------------------|---------|----------------------------------|-----------------------------------|--------------------------------|
|                                            |                    |                            |                                                     | Raw mix.   | Cement.   | Raw mix.                | Cement. |                                  |                                   |                                |
|                                            |                    | Barrels.                   | Pounds.                                             | Per cent.  | Per cent. | Pounds.                 | Pounds. | Per cent.                        | Pounds.                           | Per cent.                      |
| Alabama:                                   |                    |                            |                                                     |            |           |                         |         |                                  |                                   |                                |
| Coosa Portland Cement Co.                  | Do.                | 3,000                      | a 608                                               | 0.58       | 0.59      | 12,403                  | 6,726   | 45.8                             | 1.89                              | 7.8                            |
| Standard Portland Cement Co.               | Do.                | 2,000                      | 592                                                 | .73        | .69       | 8,643                   | 5,244   | 39.3                             | 1.70                              | 7.2                            |
| California:                                |                    |                            |                                                     |            |           |                         |         |                                  |                                   |                                |
| Cowell Portland Cement Co.                 | Do.                | 4,000                      | 608                                                 | .59        | .55       | 14,349                  | 8,360   | 41.7                             | 1.50                              | 6.2                            |
| Golden State Portland Cement Co.           | Do.                | 650                        | 648                                                 | .80        | .44       | 3,370                   | 2,283   | 67.7                             | 3.51                              | 13.5                           |
| Monolith Portland Cement Co.               | Do.                | 1,200                      | 600                                                 | .64        | .32       | 4,008                   | 3,149   | 68.3                             | 2.62                              | 10.9                           |
| Pacific Portland Cement Co., Consolidated. | Do.                | 6,000                      | 585                                                 | .50        | .50       | 17,550                  | 6,150   | 35.0                             | 1.03                              | 4.4                            |
| Riverside Portland Cement Co.              | Do.                | 5,500                      | e 594                                               | e .50      | e .22     | 11,737                  | 4,598   | 71.9                             | 2.13                              | 9.0                            |
| Santa Cruz Portland Cement Co.             | Do.                | 8,000                      | 658                                                 | .76        | .33       | 40,006                  | 10,032  | 74.9                             | 3.75                              | 14.2                           |
| Standard Portland Cement Corporation.      | Do.                | 2,500                      | 650                                                 | .47        | .33       | 7,638                   | 3,135   | 59.0                             | 1.80                              | 6.9                            |
| Colorado:                                  |                    |                            |                                                     |            |           |                         |         |                                  |                                   |                                |
| Colorado Portland Cement Co.               | Do.                | 3,000                      | 633                                                 | .78        | .56       | 14,812                  | 8,428   | 56.9                             | 2.81                              | 11.1                           |
| United States Portland Cement Co.          | Do.                | 1,500                      | 633                                                 | .72        | .42       | 6,836                   | 2,394   | 65.0                             | 2.96                              | 11.7                           |
| Georgia:                                   |                    |                            |                                                     |            |           |                         |         |                                  |                                   |                                |
| Southern States Portland Cement Co.        | Do.                | 1,500                      | 600                                                 | .98        | .73       | 8,820                   | 4,161   | 52.8                             | 3.11                              | 12.9                           |
| Illinois:                                  |                    |                            |                                                     |            |           |                         |         |                                  |                                   |                                |
| Lehigh Portland Cement Co.                 | Do.                | 5,000                      | 620                                                 | .70        | .71       | 21,700                  | 13,490  | 37.8                             | 1.64                              | 6.6                            |
| German-American Portland Cement Co.        | Do.                | 6,000                      | 620                                                 | .43        | .53       | 15,996                  | 12,084  | 24.5                             | .65                               | 2.6                            |
| Marquette Cement Manufacturing Co.         | Do.                | 7,000                      | 615                                                 | .70        | .63       | 30,135                  | 16,758  | 44.4                             | 1.91                              | 7.8                            |
| The Sandusky Cement Co.                    | Do.                | 3,500                      | 608                                                 | .88        | .59       | 18,726                  | 7,847   | 58.1                             | 3.11                              | 12.8                           |
| Indiana:                                   |                    |                            |                                                     |            |           |                         |         |                                  |                                   |                                |
| Lehigh Portland Cement Co.                 | Do.                | b 6,600                    | a 608                                               | .79        | .71       | 31,701                  | 17,807  | 43.8                             | 2.11                              | 8.7                            |
| Louisville Cement Co.                      | Do.                | 3,000                      | 600                                                 | .67        | .65       | 12,060                  | 7,410   | 38.6                             | 1.55                              | 6.5                            |
| The Sandusky Cement Co.                    | Do.                | 2,000                      | 608                                                 | .77        | .79       | 9,363                   | 6,004   | 35.9                             | 1.68                              | 13.8                           |
| Universal Cement Co.                       | Do.                | 6,000                      | 546                                                 | .80        | .29       | 9,828                   | 6,612   | 32.7                             | .54                               | 2.5                            |
| Mil No. 3.                                 | Do.                | 7,000                      | 554                                                 | .29        | .26       | 11,246                  | 6,916   | 38.5                             | .62                               | 2.8                            |
| Mil No. 4.                                 | Do.                | 13,000                     | 530                                                 | .29        | .28       | 19,981                  | 13,832  | 30.8                             | .47                               | 2.2                            |
| Mil No. 6.                                 | Do.                | 3,500                      | 625                                                 | .58        | .39       | 12,088                  | 5,187   | 59.1                             | 2.14                              | 17.1                           |
| Hawkeye Portland Cement Co.                | Do.                | b 5,053                    | 622                                                 | 1.00       | .63       | 31,000                  | 12,169  | 61.5                             | 3.82                              | 15.3                           |
| Lehigh Portland Cement Co.                 | Do.                | 6,000                      | 600                                                 | 1.08       | .99       | 38,880                  | 23,572  | 41.9                             | 2.72                              | 10.8                           |
| Northwestern States Portland Cement Co.    | Do.                | 3,000                      | 638                                                 | .55        | .50       | 10,527                  | 5,700   | 45.9                             | 1.61                              | 12.6                           |
| Kansas:                                    |                    |                            |                                                     |            |           |                         |         |                                  |                                   |                                |
| Ash Grove Portland Cement Co.              | Do.                | 1,500                      | 601                                                 | .72        | .67       | 6,484                   | 3,876   | 40.2                             | 1.74                              | 7.2                            |
| Bonner Portland Cement Co.                 | Do.                | 4,000                      | 646                                                 | .58        | .60       | 14,987                  | 9,120   | 39.2                             | 1.47                              | 11.4                           |
| Iola Portland Cement Co.                   | Do.                | 3,000                      | a 608                                               | .44        | .34       | 8,026                   | 3,876   | 51.7                             | 1.38                              | 5.7                            |
| Monarch Cement Co.                         | Do.                | 3,500                      | 640                                                 | .43        | .27       | 9,632                   | 3,591   | 62.7                             | 1.73                              | 6.7                            |
| The Western States Portland Cement Co.     | Do.                | 3,500                      | 640                                                 | .43        | .27       | 9,632                   | 3,591   | 62.7                             | 1.73                              | 6.7                            |









In a communication received from the manager of one of the large cement plants in the Lehigh Valley district the statement was made that the raw cement material used in this district contains less than 0.3 per cent. The samples analyzed in these experiments, however, indicate that in no case does the raw mix used in the plants of this district run as low as 0.3 per cent, but that some of these plants make use of cement material almost as rich in potash as may be found in any cement plant in the country. In general it may be stated, however, that high potash-bearing raw material is not characteristic of any particular part of the country.

The values given in Table I for the potash contained in the daily production of cement were obtained by multiplying the output in barrels by the weight of one barrel (380 pounds) and by the percentage of potash in the cement as found by analysis. To obtain the corresponding values for the potash in the daily run of raw mix, the output of cement expressed in barrels was multiplied by the weight of raw mix required per barrel of cement and then by the percentage of potash in the raw mix. The difference between the two values as thus determined represents the potash that escapes daily from the kilns. As shown in the table, this varies in different plants from 0.35 to 5.14 pounds of  $K_2O$  per barrel of cement produced. The average for all the plants listed in the table when consideration is taken of the variation in output of cement of the different plants amounts to 1.93 pounds<sup>1</sup> per barrel of cement.

Omitting the plants of the Universal Portland Cement Co., the corresponding average for the remainder of the 99 plants of this country from which samples were received amounts to 2.09 pounds. The average for the nine Canadian plants is 1.95 pounds. The total number of plants in this country from which samples were received is only four less than the total number which operated in 1915<sup>2</sup> and nine less than the total number said to be in operation in 1916.

The average daily output of cement from the individual plants in many cases is considered confidential information. In Table I, therefore, it was necessary to give values for the output of the individual plants which represent capacities rather than actual production. The total annual production as obtained from these values is consequently much in excess of that which is known to have been produced in any one year. The values given for the potash lost per barrel of cement are, however, independent of the output. If, therefore, the average annual production of Portland cement in

<sup>1</sup> In making this calculation no account was taken of the potash in the coal, which at most would not amount to more than a few tenths of a pound per barrel of cement. Any potash present, however, would tend to increase the value given for the amount of potash volatilized. Cf. R. K. Meade, *Portland Cement*, 2d ed., p. 179.

<sup>2</sup> Burchard, E. F., *Cement in 1915. Mineral resources of the U. S., 1915, Part II*, p. 195.



this country be now taken in round numbers as 90,000,000 barrels<sup>1</sup> and if the same average conditions be assumed to prevail in the few plants from which no samples were received as was found on an average for all other plants, then it may be estimated that the total potash ( $K_2O$ ) escaping from all the cement plants in this country as at present operated amounts to 86,850 tons annually.

The process at present most generally considered in connection with the recovery of the potash that escapes from cement kilns is electrical precipitation. The extent to which the dust may be recovered in this way is dependent, assuming proper installation, on the voltage used and the linear velocity with which the gases pass through the treater pipes. The volume of gases treated being constant, the degree of precipitation of the dust will be dependent on the extent of the installation. With present installations a recovery of approximately 99 per cent<sup>2</sup> of the dust has been obtained. It happens, however, that the finest portion of the dust escaping from any cement plant contains relatively the highest percentage of potash, and a 99 per cent recovery of the dust represents a somewhat less efficient recovery of the potash.

In the plant of the Security Cement and Lime Co., where the Cottrell process of electrical precipitation has been installed, it is found that under normal working conditions, and with a daily output of 2,500 barrels, the dust collected in the kiln stacks amounts to 16,000 pounds and in the treaters 45,000 pounds every 24 hours. The former contains on an average 4.5 per cent potash, and the latter, as analyzed in this laboratory, 11.4 per cent, making a total of 5,850 pounds of potash recovered daily. As shown in Table I, the potash lost from the kilns during the same period amounts to 6,525 pounds. On this basis of calculation the potash recovery in this plant amounts to 90 per cent of the total. If this value be accepted as the efficiency of recovery of the potash in the most economic installations, then the total recoverable potash in the cement plants of this country under present working conditions amounts to 78,165 tons annually.

The potassium compounds occurring in cement dust may be divided into three groups, as follows: (1) Those which are readily soluble in water; (2) those which are slowly soluble; and (3) those which are insoluble.

The insoluble potash represents the combinations occurring in the original silicates of the raw mix carried over mechanically in the dust before being subjected to a sufficiently high temperature to bring about decomposition. The form of combination which is slowly soluble in water is supposed to be due to a recombination of the vola-

<sup>1</sup> Burchard, E. F. Loc. cit.

<sup>2</sup> Schmidt, W. A., Paper presented at the meeting of the American Institute of Mining Engineers, Globe, Ariz., Sept. 21, 1916.

tilized potash with the silicates in the dust. In some plants where coal is used for burning the extent to which the potash occurs in this "recombined" form may be considerable, while in certain other plants where oil is used for fuel this combination of the potash occurs in comparatively small amount. In Table II the percentages of the different forms of potash occurring in a dust from a plant which uses oil for fuel and also from one which uses coal are given:

TABLE II.—Percentages of the different combinations of potash in flue-dust samples from different sources.

| Combination.                        | Cement dust from—             |                              |
|-------------------------------------|-------------------------------|------------------------------|
|                                     | Riverside Portland Cement Co. | Security Cement and Lime Co. |
|                                     | <i>Per cent.</i>              | <i>Per cent.</i>             |
| Acid-insoluble potash, $K_2O$ ..... | 0.2                           | 0.5                          |
| Slowly soluble potash.....          | .7                            | 4.1                          |
| Water-soluble potash.....           | 9.8                           | 6.8                          |
| Total.....                          | 10.7                          | 11.4                         |

The determinations of the soluble potash in these samples were made by boiling 10 grams of the sample in 500 cubic centimeters of water for one-half hour as directed in the Methods of the Association of Official Agricultural Chemists. The insoluble potash was assumed to be that portion of the total potash which remained insoluble after boiling in a 5 per cent solution of hydrochloric acid. The difference between the total potash and the sum of the soluble and insoluble portions was then taken as the proportion of the potash which is slowly soluble in water.

In a previous publication it was shown, as already stated, that the greater part of the potash in feldspar may be made to pass into solution by digesting with lime under a steam pressure of 10 to 15 atmospheres. In cement dust as it escapes from the kilns the slowly soluble and the insoluble potash already are associated with a considerable percentage of free lime and consequently it was thought that the greater part of these constituents might be recovered in soluble form by digesting the dust with steam alone under pressure. This has been found to be the case, and with the Security cement dust it has been found possible to recover in this way in soluble form and with little increase in pressure upward of 95 per cent of the total potash present. If it be assumed, therefore, that it would be practicable to recover, or render available, say, 95 per cent<sup>1</sup> of the potash in the recoverable dust of cement plants, then the recoverable and available potash escaping from the cement plants of this country amounts

<sup>1</sup> In the case of coal-fired plants it may not be possible, with present commercial apparatus, to render soluble as much as 95 per cent of the collected potash, but there is no doubt that as details of commercial apparatus are perfected this value will represent a fair average for the different plants of the country.

approximately to 75,000 tons annually. If, however, the dust from all plants losing less than 1 pound of potash per barrel of cement be considered as too low grade for use as a source of fertilizer material and the figures from such plants be omitted in the calculations, then the value for the available recoverable potash in the cement industry of this country as normally operated becomes 71,000 tons annually.

#### PERCENTAGE OF VOLATILIZATION OF POTASH IN CEMENT PLANTS.

As shown in Table I, the proportion of the total potash ( $K_2O$ ) that is volatilized varies in different plants from 24.5 to 95.9 per cent. The lowest values were obtained for plants widely separated from one another. In the Hudson River district the percentage volatilization varies from about 30 per cent to 45 per cent, and in the Lehigh Valley district from about 40 per cent to 60 per cent. In plants situated in the northern Central States considerable variation was noted. The highest values were found for plants located in southern California, and in Colorado and Utah.

It may be pointed out that as much variation occurs in the percentage of potash volatilized from plants using oil as from those using coal. It is also to be noted that the average percentage volatilization (46 per cent) in plants using the wet process is almost as great as that (47 per cent) in plants using the dry process, and in fact the highest percentage volatilizations, 95.9 per cent and 90.7 per cent, were found for plants using the wet process. This result is contrary to what seems to have been the general opinion among cement manufacturers, as indicated by the following excerpts from communications received from two firms using the wet process: (a) "Our plant is a wet-process plant, and the amount of potash which goes up in the air we figure is infinitesimal as compared with plants using the dry process of manufacture." (b) "In our manufacture of Portland cement we use the wet method of grinding our raw materials and in a short time I believe the entire cement industry will depart from the present dry method and adopt the wet method so that there will be no more precipitation of volatilized potash in our smokestacks."

That a smaller proportion of dust should be carried over mechanically in the wet-process plants is to be expected, and the loss of dust should be particularly reduced in those plants in which the kilns are provided with cross-partition plates which continuously raise the wet slurry and allow it to fall again as a spray. Judging from the observations that have been made in other industries, however, it is not so apparent that the wet process should retard very greatly the escape from the kilns of that portion of the potash which actually is volatilized.



Thus, R. J. Wysor<sup>1</sup> has shown in an investigation on the escape of potash from blast furnaces that the specially designed tower spray washers used for purifying the gas from the blast furnace are only moderately efficient in freeing the gas from the finest dust particles, and that much of the water-soluble alkalies remains in the gas current after leaving the washers. This result is explained on the ground that the particles of fume are in such an exceedingly fine state of division that they escape contact with the relatively large drops of water.

Experiments to show the effect of variations in burning on the volatilization of potash have been made recently at the plant of the Security Cement and Lime Co. It was found that as the burning conditions were varied from normal to such a temperature as to give overburned clinker, the percentage volatilization of the potash increased from 31.6 per cent to 42.6 per cent.<sup>2</sup>

A similar result was obtained also in this laboratory in the analysis of seven cement samples furnished us by the Tidewater Portland Cement Co. The samples were collected successively as the burning was raised from a temperature giving a very soft clinker to that sufficient to make a very hard clinker. Corresponding samples of raw mix were collected at the same time, giving a composite sample which analyzed 0.71 per cent potash. The results obtained in the analysis of the cement samples are shown in Table III.

TABLE III.—*Effect of variable burning on the liberation of potash in cement kilns.*

| Sample.              | Potash in<br>clinker. | Proportion<br>of total<br>potash<br>volatilized. | Sample.              | Potash in<br>clinker. | Proportion<br>of total<br>potash<br>volatilized. |
|----------------------|-----------------------|--------------------------------------------------|----------------------|-----------------------|--------------------------------------------------|
|                      | <i>Per cent.</i>      | <i>Per cent.</i>                                 |                      | <i>Per cent.</i>      | <i>Per cent.</i>                                 |
| No. 1 <i>a</i> ..... | 0.69                  | 40.0                                             | No. 5.....           | 0.51                  | 55.6                                             |
| No. 2.....           | .70                   | 39.1                                             | No. 6.....           | .44                   | 61.7                                             |
| No. 3.....           | .58                   | 49.5                                             | No. 7 <i>b</i> ..... | .48                   | 58.4                                             |
| No. 4.....           | .54                   | 50.7                                             |                      |                       |                                                  |

*a* Very soft.

*b* Very hard.

These results show that the potash volatilized increases with the temperature of burning, but the increase apparently is not sufficient to attribute the great variation in the potash volatilized in different plants entirely to differences in the temperature of burning.

That it is possible also to bring about by chemical means an increase in the amount of potash volatilized has been demonstrated recently at the plant of the Security Cement and Lime Co. This is effected by adding ordinary salt both to the raw mix and to the coal used for fuel, and in such quantity that the total added amounts

<sup>1</sup> Bul. Am. Inst. Mining Engineers, 121, 1 (1917).

<sup>2</sup> Anderson and Nestell. Loc. cit.

to 1 per cent of the raw mix. The salt is added in the solid state and is brought into intimate mixture with the raw mix and coal by being ground with these materials. The quality of the resulting cement is in no sense impaired by the addition of the salt, for it is found that the total alkalies in the clinker when salt is added to the charge are actually less than when no salt is added, due to the fact that the percentage of the potash is reduced more than the percentage of the soda is increased. By this treatment the percentage of the potash volatilized, which at this plant normally runs about 38 per cent, is increased to about 65 per cent. Assuming that this percentage volatilization (65 per cent) could be attained by chemical or other means in all plants where a lower volatilization normally prevails, then it may be estimated that the recoverable available potash in the cement plants of this country would be increased from 71,000 tons to 101,000 tons annually. In making this calculation it is assumed as before that 90 per cent of the total potash volatilized is recovered, but that the additional recoverable potash is all available.

Other processes that have been proposed for bringing about an increase in the volatilization of the potash involve treatment with such reagents as calcium chloride,<sup>1</sup> calcium fluoride,<sup>2</sup> sulphur dioxide,<sup>3</sup> and steam.<sup>3</sup>

The method of increasing the volatilization of the potash by use of calcium fluoride as proposed by Huber and Reath<sup>4</sup> has been tested on a commercial scale and is worthy of special mention. In this process the fluorine compound is first added to the argillaceous component of the cement material in the form of fluorite and in quantity approximately equivalent to the potassium present. This material is then properly proportioned with limestone to give normal Portland-cement raw mixture and burned in a rotary kiln in the usual way. Volatilization of the potash under these conditions largely takes place in the form of the fluoride, which, as it escapes from the kilns, becomes associated with the salts of calcium carried over mechanically in the dust. It thus happens that when the dust is leached with hot water the potash passes into solution as sulphate or carbonate, while the fluorine remains behind as insoluble calcium fluoride. On using the residue as cement material the same fluorine is fed into the furnace again and may thus be repeatedly used in bringing about increased volatilization of the potash.

<sup>1</sup> Herstein, B., *J. Ind. Eng. Chem.*, **3**, 426 (1911); Ross, William H., *Circ. No. 71*, Bureau of Soils; Brown, H. E., U. S. Patents Nos. 1,123,341 and 1,124,238; Ellis, C., U. S. Patent No. 1,186,522; Spackman, H. S., and Conwell, E. L., U. S. Patent No. 1,202,327.

<sup>2</sup> Ellis, C., U. S. Patent No. 1,186,522; Huber, A. W., and Reath, F. F., U. S. Patents Nos. 1,194,344 and 1,219,315; Spackman, H. S., and Conwell, E. L., U. S. Patent No. 1,202,327.

<sup>3</sup> Spackman, H. S., and Conwell, E. L., U. S. Patent No. 1,202,327.

<sup>4</sup> *Loc. cit.*

## RELIABILITY OF THE RESULTS OBTAINED.

All potash determinations were made by the J. Lawrence Smith method, modified by converting the chlorides into sulphates to insure against loss of potash on driving off ammonium salts and then proceeding as in determining water-soluble potash according to the Methods of the Association of Official Agricultural Chemists. The duplicate determinations in every case were made by different persons and each percentage value for potash in raw mix and in cement thus represents the mean of the results found by two analysts. No percentage values of which a mean was taken differed by more than 0.12, and most differences in results were well within this limit.

When requesting samples for analysis from the different plants attention was called to the importance of selecting cement and raw-mix samples which correspond as closely as possible with one another, and which were representative of normal working conditions. This request seems to have been observed by most if not all plants, and judging by letters received it appears that a great deal of care was taken by many cement officials in collecting the samples. Each sample selected for analysis was reduced to a fineness of 175 mesh by grinding the portion which failed to pass through the screen, first in a steel-ball mill and then by hand in an agate mortar. The mills were not asked to make a distinction between the ground clinker and finished cement, for the extent to which these would differ in composition in any particular case through the addition of gypsum to the former was not thought sufficient to have any material effect on the results.

Analyses corresponding to those given in Table I have been made by the Western Precipitation Co.<sup>1</sup> of samples from five of the plants listed in the table. The results obtained are compared with those found in this laboratory in Table IV:

TABLE IV.—*Comparison of results of analyses made by the Western Precipitation Co., and by the Bureau of Soils of raw-mix and cement samples collected on different occasions.*

| Company.                            | Potash in raw mix. |                           | Potash in cement. |                           |
|-------------------------------------|--------------------|---------------------------|-------------------|---------------------------|
|                                     | Bureau of Soils.   | Western Precipitation Co. | Bureau of Soils.  | Western Precipitation Co. |
|                                     | <i>Per cent.</i>   | <i>Per cent.</i>          | <i>Per cent.</i>  | <i>Per cent.</i>          |
| Olympic Portland Cement Co. ....    | 0.56               | 0.42                      | 0.51              | 0.45                      |
| Pacific Portland Cement Co. ....    | .50                | .52                       | .50               | .43                       |
| Santa Cruz Portland Cement Co. .... | .76                | .76                       | .33               | .28                       |
| Portland Cement Co. of Utah. ....   | .94                | .92                       | .24               | .21                       |
| Security Cement and Lime Co. ....   | 1.29               | 1.12                      | 1.05              | 1.02                      |

<sup>1</sup> Written communication.



The two sets of analyses shown in this table were made on different samples collected from four months to six months apart. The close agreement in each case affords evidence that at least for these plants the samples collected are representative, and that the potash content of the raw material used in cement manufacture is surprisingly uniform.

Further evidence in support of this conclusion is available. Thus, R. K. Meade, consulting engineer for the Clinchfield Portland Cement Co., reports<sup>1</sup> that he found 2.49 pounds of potash volatilized at this plant per barrel of cement, basing his calculations on the results of analyses of samples secured about a year prior to the time that our samples were obtained. This result differs but 0.03 pound from that given in Table I. Again, of two samples of raw mix which were collected and forwarded to this laboratory nine months apart by the Tidewater Portland Cement Co., both were found to contain 0.71 per cent potash.

It may be pointed out also that as a rule those plants which are situated near one another and apparently use material from the same geological formation show much the same potash content in the raw material used. Thus, there may be compared in this connection the different plants at Bath, Pa.; Nazareth, Pa.; Fenton, Mich.; Mason City, Iowa; Concrete, Wash.; and Hudson, N. Y.

The values listed in Table I for the weights of dry raw mix required per barrel of cement show greater variation than might be expected, and it is possible that some of the values given may depart somewhat from values representing true working conditions. Where no values could be obtained it was assumed that 608 pounds of raw mix would be required per barrel of cement. It is recognized, also, that in individual cases the samples collected may not be representative of normal working conditions, but from the observations made it is thought that in the majority of cases the results given are representative.

#### ESTIMATED PERCENTAGE OF POTASH IN THE FLUE DUST FROM DIFFERENT PLANTS.

The percentage of potash occurring in the flue dust from any plant will vary (1) with the percentage of potash in the raw material; (2) with the percentage of potash volatilized; and (3) with the amount of dust carried off from the kilns mechanically.

As already pointed out, the quantity of dust collected daily in the flue stacks and treaters of the plant of the Security Cement and Lime Co. amounts to about 61,000 pounds. If it be assumed that this represents a recovery of 95 per cent of the total dust,

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<sup>1</sup> Written communication.

then the total dust escaping from the kilns of this plant amounts to about 4 per cent of the charge fed into the kilns. If it be assumed that the dust thus collected has undergone about 50 per cent calcination, then the true loss of raw mix in the form of dust will amount to 5 per cent, which is recognized to be a fair average for the plants of this country using the dry process. In calculating the values given in the last column of Table I, the dust lost from the kilns in plants using this process was accordingly taken as 4 per cent.

On this basis of a 4 per cent loss as dust, the potash contained in the dust from the Security plant should amount to 10.9 per cent. It happens, however, that 27 per cent of the dust, containing about 4.5 per cent of potash, is collected in the flue stacks which connect the kilns with the treaters, and, therefore, the remaining dust, assuming a 90 per cent precipitation of the potash, should contain 11.1 per cent of potash. A sample of this dust analyzed in this laboratory was found to contain 11.4 per cent of potash.

The quantity of dust lost from plants using the wet process is dependent on a number of factors, such as the dimensions of the kiln, the amount of water in the slurry, and the plasticity of the raw mix. Estimates which have been given the writers vary between rather wide limits. On the basis of the most reliable information obtained, it is probable that a loss as dust amounting to 2 per cent of the raw mix is a fair average. This value was therefore used in estimating the percentage of potash in the dust from wet-process plants. The actual potash content of the dust escaping from any plant will be greater or less than the values given according as the true percentage of dust lost is less or greater than the value cited.

As shown in experiments which are to be described in detail in a subsequent publication, the usual constituents of the water extract of freshly collected flue dust are sulphates, chlorides, sulphides, and polysulphides of potash, soda, and lime. Chlorides occur only in small amounts. The percentage of sulphides and polysulphides in the dust from different plants may vary greatly, and in some cases they may be entirely absent. Free lime is found in all cement dust, and in the water extract of all samples analyzed the basic radicals were found to be in excess. It follows, therefore, that the potash in the water extract of freshly collected flue dust will be present to a greater or less extent in the form of the hydroxide. As the dust becomes carbonated either by chemical treatment or by exposure to the air, the hydroxides present will change into carbonates, and the water-soluble potash then will be obtained principally in the form of the sulphate, which is the form universally recognized as of most value for use as a fertilizer.

The flue dust as collected by electrical precipitation may be (1) used directly as a source of cement material; (2) disposed of as collected for use as a fertilizer or in fertilizer manufacture; or (3) leached

with a view to preparing concentrated potash salts. The value of the dust as a source of cement material is estimated usually at about 75 cents per ton. The value of potash in the form of sulphate depends on the concentration and varies at normal wholesale prices from about 70 cents per unit for low-grade material to about 90 cents per unit in material containing a minimum of 48 per cent potassium sulphate, or to 95 cents in material containing a minimum of 90 per cent potassium sulphate. Thus it is seen that a comparatively low percentage of potash in flue dust is sufficient to give it more value as a source of potash than as cement material. By separating and concentrating the potash occurring in flue dust the price thereof per unit is increased, the cost of transportation is reduced, the residue becomes available for cement manufacture, and if the process of separation involves some such treatment as steaming under pressure, the percentage of available potash in the dust of some plants at least may be increased considerably. Against these advantages incident to the separation of the dust must be balanced the relative cost of the operation, which will be dependent on the percentage of potash in the dust. The best method of disposing of the dust is thus dependent on a number of factors which will vary with conditions, and it thus happens that all of the three procedures referred to for utilizing the dust are now being given practical application in plants where the dust is being collected by electrical precipitation.

The work so far done on the recovery of potash from cement plants apparently has been limited to plants using the dry process. No installation for the electrical recovery of the dust has yet been made in plants using the wet process, but it is probable that the electrical method would prove just as applicable to plants of this kind as to those using the dry process. At the temperature at which the gases leave the kilns no precipitation of water would take place, and as long as the temperature of the gases is maintained above 100° while passing through the treater pipes little condensation of moisture should occur. The dust in all probability would be precipitated either in a dry state or as a mud or slurry. If precipitated in the form of a slurry, no electrode hammering system would then be necessary, for the precipitated material would flow down the pipes continuously and a concentrated solution of salts would thus be obtained directly without the necessity of any special treatment.

#### RATIO OF POTASH TO SODA IN CEMENT DUST.

The extent to which the potash salts in flue dust may be concentrated conveniently is dependent in a large measure on the proportion of sodium salts also present in the dust. It was, therefore, thought advisable to determine the proportion to be expected for a number of plants with a view to gaining some idea as to the quantity of soda that might be contained in the dust. The results are given in Table V.



TABLE V.—Comparison of the amounts of potash and soda lost in cement manufacture.

| Company.                                | Plant.         | Raw mix.    |             | Cement.     |             | Loss from kilns. |             | Ratio of per-centage losses. | Loss per barrel of cement. |           | Ratio of potash to soda in fine dust. |
|-----------------------------------------|----------------|-------------|-------------|-------------|-------------|------------------|-------------|------------------------------|----------------------------|-----------|---------------------------------------|
|                                         |                | Pot-ash.    | Soda.       | Pot-ash.    | Soda.       | Pot-ash.         | Soda.       |                              | Pot-ash.                   | Soda.     |                                       |
| Alpha Portland Cement Co.               | Martin's Creek | P. ct. 0.92 | P. ct. 0.48 | P. ct. 0.77 | P. ct. 0.50 | P. ct. 49.1      | P. ct. 36.7 | 1.34                         | Lbs. 2.82                  | Lbs. 1.10 | 2.56                                  |
| Clinchfield Portland Cement Co.         | .....          | .77         | .39         | .63         | .48         | 50.6             | 25.8        | 1.96                         | 2.46                       | .63       | 3.90                                  |
| Cowell Portland Cement Co.              | .....          | .59         | .43         | .55         | .49         | 41.7             | 28.8        | 1.45                         | 1.50                       | .75       | 2.00                                  |
| Edison Portland Cement Co.              | .....          | .69         | .59         | .70         | .49         | 39.8             | 50.7        | .78                          | 1.76                       | 1.91      | .92                                   |
| Grant Portland Cement Co.               | Egypt          | .77         | .52         | .59         | .57         | 54.5             | 34.9        | 1.56                         | 2.69                       | 1.16      | 2.32                                  |
| Iola Portland Cement Co.                | .....          | .58         | .54         | .60         | .61         | 39.2             | 33.6        | 1.17                         | 1.47                       | 1.17      | 1.26                                  |
| Knickerbocker Portland Cement Co.       | .....          | .81         | .50         | .78         | .59         | 38.3             | 24.4        | 1.57                         | 1.84                       | .72       | 2.56                                  |
| Lawrence Portland Cement Co.            | .....          | 1.01        | .53         | .88         | .55         | 45.7             | 35.4        | 1.29                         | 2.82                       | 1.14      | 2.47                                  |
| Lehigh Portland Cement Co.              | Fogelsville    | .71         | .45         | .47         | .38         | 58.6             | 47.2        | 1.24                         | 2.53                       | 1.29      | 1.96                                  |
| Do.                                     | Mitchell       | .79         | .61         | .71         | .71         | 43.8             | 27.2        | 1.61                         | 2.11                       | 1.01      | 2.09                                  |
| Do.                                     | Orinod         | .63         | .39         | .38         | .52         | 62.2             | 16.4        | 3.70                         | 2.37                       | .39       | 6.07                                  |
| Do.                                     | Mason City     | 1.00        | .50         | .63         | .61         | 61.5             | 25.5        | 2.41                         | 3.82                       | .79       | 4.84                                  |
| Marquette Portland Cement Co.           | .....          | .70         | .58         | .63         | .66         | 44.4             | 29.7        | 1.49                         | 1.91                       | 1.06      | 1.90                                  |
| Nazareth Cement Co.                     | .....          | .84         | .61         | .64         | .60         | 53.3             | 39.7        | 1.34                         | 2.78                       | 1.50      | 1.85                                  |
| Northwestern States Portland Cement Co. | .....          | 1.08        | .43         | .99         | .44         | 41.9             | 38.3        | 1.09                         | 2.72                       | 1.04      | 2.62                                  |
| Pacific Portland Cement Co.             | .....          | .50         | .71         | .50         | .98         | 35.0             | 10.3        | 3.40                         | 1.03                       | .43       | 2.40                                  |
| Portland Cement Co. of Utah.            | .....          | .94         | .70         | .24         | .55         | 84.9             | 45.2        | 1.88                         | 5.14                       | 2.04      | 2.52                                  |
| Texas Portland Cement Co.               | .....          | .90         | .37         | .81         | .45         | 43.9             | 24.2        | 1.81                         | 2.41                       | .55       | 4.38                                  |
| Vulcanite Portland Cement Co.           | .....          | .58         | .36         | .58         | .41         | 40.6             | 32.4        | 1.25                         | 1.51                       | .75       | 2.00                                  |
| Whitehall Portland Cement Co.           | .....          | .77         | .58         | .58         | .66         | 50.6             | 25.4        | 1.99                         | 2.26                       | .85       | 2.66                                  |

Table V shows that for those cases examined the percentage of potash in the raw mix with one exception is in excess of the percentage of soda. With one-exception, also, the percentages of potash volatilized are considerably in excess of the corresponding values found for soda. It consequently happens that the calculated excess of potash over soda in the dust is in most cases quite marked, the ratio of potash to soda varying in the case of the samples examined from 0.92 to 6.07, with an average of 2.66.

#### POTASH-PRODUCING PLANTS IN THE UNITED STATES.

The recovery of the potash which escapes from the stacks of cement kilns was first made at the plant of the Riverside Portland Cement Co., using the Cottrell process of electrical precipitation. The first unit of this installation was completed in 1912, and has been in continuous operation ever since. The following year the installation was enlarged to take care of the gases from 10 kilns, which comprised all the kilns in the plant at that time. This main installation is built on the plate and wire principle,<sup>1</sup> wherein flat

<sup>1</sup> Schmidt, W. A., loc. cit.; U. S. Patent No. 1,200,887.

plates take the place of the pipes used in later installations as collecting electrodes and the gases flow horizontally between the plates instead of vertically as is the case where pipes are used. Two kilns were later added to the equipment of the original plant, and to take care of the gases from these kilns the multiple-pipe system was installed.

In the case of the plate and wire treater a separation of the dust according to the size of the particles is in a measure effected during the process of precipitation, and it thus happens that the fineness of the dust collected and the percentage of potash present in the precipitated dust increase with the distance of the collecting hoppers from the kilns. In the multiple-pipe treater, however, no separation of the dust takes place other than that brought about by deposition of dust in the flues connecting the treater with the kilns. This dust is coarser and contains a lower percentage of potash than the average of that precipitated.

In the original method used for taking care of the material precipitated at this plant all of the collected dust was burned in one of the kilns connected with the multiple-pipe treater, and the dust there precipitated separately collected. The dust thus recovered on second precipitation showed a marked concentration of potash, which sometimes ran as high as 20 to 23 per cent. This process of concentrating the potash was abandoned later, as it was found that the potassium sulphate in the treater dust was less readily volatilized than the potash in the original mix, and although a high-grade potash material could be obtained in this way the double treatment actually resulted in a loss of potash, due to the comparatively greater percentage contained in the final clinker.

In the method now followed for disposing of the collected material the coarse dust which settles in the long connecting flue of the multiple-pipe treater and in the two rows of hoppers nearest the kilns in the plate and wire treater is returned to the kilns for use as cement material. The dust precipitated in the multiple-pipe treater and in the two remaining rows of the plate and wire treater is separately collected and is either disposed of directly for use as a fertilizer or leached with water at a temperature above  $85^{\circ}$  for the preparation of concentrated potash salts.<sup>1</sup> By the use of feldspar the potash in the raw mix at this plant has recently been increased considerably above the value given in Table I, with corresponding gains in the quantity of potash volatilized and recovered.

In the plant of the Security Cement and Lime Co. the multiple-pipe system alone is used. In this installation the original flue stacks are still retained, and each serves as part of the connecting flue which conducts the gases from the corresponding kiln or kilns to the treater with which it is connected. By this indirect method of connecting the kilns with the precipitating system the gases before

<sup>1</sup> Huber, F. W., and Reath, F. F., U. S. Patent No. 1,220,989.

entering the treaters are cooled by radiation in the flues to the desired temperature for the precipitation of the dust.

Several precipitating installations are also in operation at plants controlled by the Universal Portland Cement Co., but as indicated in Table I the dust from these plants is too low grade to be of value as a source of potash. The dust collected in the treaters at these plants, therefore, is returned to the kilns automatically, for use as cement material.

In the precipitating system recently installed at the Cementon plant of the Alpha Portland Cement Co., the gases from the kilns are passed successively through a boiler and economizer system before entering the treaters. In this way the waste heat of the gases is utilized for the generation of power by steam turbines. In this installation, as well as in the multiple-pipe treaters already referred to, an artificial draft produced by a fan placed beyond the treater system replaces the natural draft originally given by the flue stacks.

The advantages claimed for installations of the kind last mentioned are as follows: (1) The abatement of the dust nuisance is effectively secured; (2) material is recovered suitable as a source of potash or cement material or of both when separation of the potash is brought about; (3) a greater efficiency in the burning of the cement is secured owing to better possible regulation of the draft through the kilns, with resultant economy in the amount of fuel required; and (4) utilization of the waste heat of the gases from the kilns.

In the plant of the California Portland Cement Co. use is made of the Fleming patent dust-collecting system.<sup>1</sup> This system has been in operation since 1912, and it is claimed that this method of collecting the dust is not only efficient but it is also more than self-supporting, there being a saving to the company in the dust collected, a larger output per barrel of oil used for fuel, and fewer shutdowns than before the Fleming system was installed.

The draft for the kilns is produced by fans sucking at the end of separate flues. Instead of discharging the gases into the atmosphere, these fans blow the dust and fumes into a large dry dust-settling chamber, where the velocity of the gases is reduced 90 to 95 per cent and about two-thirds of the dust is deposited. The gases carrying the extremely fine dust which does not settle then go to wet washing chambers, where they are forced up and down several times through a system of seven baffle sections in each of which are sprays of water for capturing the remaining dust. In both the wet and dry chambers means are provided for removing the collected dust to the cement kilns. The same water being repeatedly used in the wet baffle chambers, it soon becomes charged with soluble salts, principally in the form of sulphur compounds of potassium, sodium, and calcium. When more than one-half pound per cubic foot is found some of the solution is removed and replaced by fresh water in order not to cause trouble

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<sup>1</sup> Hanna, W. C., *Metallurgical and Chemical Engineering* 13, 609 (1915).



with the sprays. Steps are now taken to recover the potash, but further details of the operation are held confidential.

Extensive experiments on a wet process for the recovery of potash in cement dust have also been made at the plant of the Sandusky Cement Co. One method of procedure as outlined in a patent<sup>1</sup> granted to the president of this company has for its object the recovery of the water-soluble potash in the dust. This is done (1) by causing the gases to pass over water contained in shallow vessels in which the solution of alkali salt is produced and replaced as it becomes saturated, or (2) by causing the gases to pass upward through a tower filled with an open checkerwork of brick at the top of which a spray of water is introduced. The flue is so adjusted that most of the water is evaporated in its descent over the extensive brickwork surface in contact with the gases and a small stream only of a concentrated salt solution is discharged continually at the bottom of the tower.

In a process described in the specifications of a subsequent patent<sup>2</sup> provision is also made for the recovery of the insoluble potash in the dust and for utilizing the waste heat of the gases. This is done by passing the gases first through suitable dust chambers and then successively through a boiler and economizer system before passing into the spray system as outlined in the preceding patent. The dust which is deposited in the connecting flues of the system and the mud which settles out from the concentrated salt solutions are then returned to the kilns for the purpose of volatilizing the potash present with a view to its ultimate recovery in soluble form. The experiments on the commercial application of the methods outlined in these patents have not yet been completed. It seems doubtful, however, from observations made in various industries on the use of spray washers for the purification of gases from a suspended fume, whether any wet process will prove as effective as the electrical process for the recovery of potash from cement flue dust.

The recovery of potash from feldspar by use of the latter in the manufacture of cement has recently been investigated on a commercial scale by the Buffalo Potash & Cement Corporation, operating under the Brown<sup>3</sup> and Warren<sup>4</sup> patents.

In the process outlined in these patents feldspar is ignited in an oxidizing atmosphere with a sufficient quantity of calcium chloride to furnish sufficient chlorine to combine with the potassium in the feldspar and with a sufficient quantity of calcium carbonate to bring the lime content of the resulting material up to 40 to 55 per cent. The charge is burned in a modified type of copper blast furnace at a temperature practically the same as that required in Portland-cement practice with rotary kilns. Under the conditions of the operation the charge is reduced to a molten mass yielding a cement containing no

<sup>1</sup> Newberry, S. B., U. S. Patent No. 1,121,532.

<sup>2</sup> Newberry, S. B., U. S. Patent No. 1,150,295.

<sup>3</sup> U. S. Patents Nos. 1,123,841 and 1,124,238.

<sup>4</sup> U. S. Patent No. 1,123,964.

free lime and at the same time a high percentage volatilization of the potash is obtained. A combined dry and wet system was first used for recovering the potash, but, not proving satisfactory, this has been replaced by the Cottrell process of electrical precipitation.

#### ACKNOWLEDGMENT.

We wish to express our thanks to the different cement companies listed in Table I for the samples they have furnished us, and particularly to the officials of the Security Cement and Lime Co., the Western Precipitation Co., Mr. R. K. Meade, and others, for the information they have given us.

#### SUMMARY.

(1) Analysis of samples of raw mix and of cement from 113 cement mills in the United States and Canada shows that the potash in the raw mix varies from 0.20 to 1.16 per cent, and that the percentage of potash volatilized in the different plants varies from 24.5 to 95.9 per cent. From the results thus obtained it has been calculated that the potash escaping from the kilns of these plants ranges from 0.35 to 5.14 pounds per barrel of cement produced, with an average for the plants of this country of 1.93 pounds. On the basis of an average production of 90,000,000 barrels, the total potash escaping from the cement plants of this country amounts to about 87,000 tons annually. It has been demonstrated commercially that 90 per cent of the potash escaping in the dust is recoverable, and from experiments made in this laboratory it would appear that 95 per cent of the recoverable potash is, or may readily be made, available. The recoverable potash in the cement industry therefore amounts to approximately 78,000 tons and the available recoverable potash to 75,000 tons, or to 71,000 tons when plants losing less than 1 pound of potash per barrel of cement are omitted.

(2) Assuming, in the light of results that have already been obtained, that it would be practicable to increase the percentage of potash volatilized to at least 65 per cent for all plants, then the available recoverable potash would amount to more than 100,000 tons annually, or to nearly one-half of the normal consumption of potash in this country.

(3) If it be assumed, further, that the dust escaping from the kilns amounts on an average to 4 per cent of the raw mix fed into the kilns in the case of dry-process plants, and to 2 per cent for plants using the wet process, then, on the basis of the results already given, the total potash content of the dust escaping from the former plants will vary in different plants from 1.4 to 20.0 per cent, and in the latter from 9.1 to 35.1 per cent.

(4) The ratio of potash to soda in the dust as determined for 20 different plants varies from 0.92 to 6.07, with an average of 2.66.

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# UNITED STATES DEPARTMENT OF AGRICULTURE



## BULLETIN No. 573

Joint Contribution from the Bureau of Plant Industry, WM. A. TAYLOR, Chief, and the Bureau of Animal Industry A. D. MELVIN, Chief



Washington, D. C.

August 4, 1917

## THE SHEEP INDUSTRY ON THE MINIDOKA RECLAMATION PROJECT.<sup>1</sup>

By E. F. RINEHART, *Agriculturist, Demonstrations on Reclamation Projects, Bureau of Plant Industry.*

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### IMPORTANCE OF SHEEP PRODUCTION ON GOVERNMENT RECLAMATION PROJECTS.

Two of the leading factors influencing the development of agriculture on the Government reclamation projects are the isolated location of these irrigated regions and the local conditions necessitating or favoring the production of forage and grain crops, which ordinarily will not bear the cost of transportation to the large consuming centers. It follows that the development of these irrigated lands requires the establishment of live-stock industries, in which

<sup>1</sup> This bulletin has been prepared under the direction of Mr. F. D. Farrell, Agriculturist in Charge of the Office of Demonstrations on Reclamation Projects of the Bureau of Plant Industry, as a part of the work of that office in the development of agricultural industries on the Government reclamation projects. That part of this work which relates to live-stock production is conducted in cooperation with the Bureau of Animal Industry. The suggestions made in this bulletin, while based primarily on the results of observations on the Minidoka Reclamation Project, are applicable to several other irrigation projects in the northwestern United States having similar climatic and agricultural conditions.

the chief crops produced can be utilized locally and the products marketed at a profit. The failure in recent years of live-stock production in the United States to keep pace with the rapidly increasing demand for live-stock products has resulted in high prices for these commodities, and this has intensified the irrigation farmer's interest in animal industries.

The national deficiency of live-stock products has been more acute with respect to sheep than any other class of farm animals. The strong demand for wool and mutton, together with a decreasing national supply, has resulted in extremely high prices during recent years. These facts have directed the attention of an increasing number of irrigation farmers to the possibilities of sheep production on irrigated lands.

The interest in sheep production has been particularly noticeable on the Minidoka Reclamation Project. Since the writer was stationed on the project in October, 1914, there has been a rapidly increasing demand for information regarding methods of sheep production, and the local sheep industry has experienced steady development. During the past two years, special attention has been paid to sheep production, and information has been secured bearing on the problems with which irrigation farmers are confronted in the development of the industry.

This bulletin has been prepared with special reference to the Minidoka project, but it should also be of value to farmers interested in sheep production on other reclamation projects where the conditions are similar. In order to give a general understanding of the conditions under which sheep are produced on the Minidoka project, the more important climatic and agricultural features of the district are briefly described.

#### AGRICULTURAL CONDITIONS ON THE MINIDOKA PROJECT.

The Minidoka Reclamation Project is situated in the Snake River Valley of Idaho, 70 miles west of the town of Pocatello. The project contains approximately 120,000 acres, somewhat more than half of which lies on the north side of the river under the gravity irrigation system, the remainder lying on the south side being irrigated by pumping. Surrounding the project on all sides are wide sagebrush plains, large areas of which are now being settled and reclaimed by dry farmers. On the north lies an area approximately 90 miles wide including sagebrush plains, a small irrigated valley, and a mountainous range area, beyond which the Sawtooth National Forest is located. To the south there is an area of public land which is being taken up by dry farmers, and beyond this is a mountainous range area, including the Minidoka National Forest. Cattle and sheep are grazed in the mountainous ranges during the summer. On the



sagebrush plains the grass is good from April to June, and again after the fall rains, usually from October to December.

The average elevation of the irrigable area of the project is 4,225 feet. The annual precipitation averages 14 inches, most of which occurs during the winter months. The annual range of temperature is from  $-20^{\circ}$  to  $100^{\circ}$  F. The irrigation season extends from April 1 to October 31. The principal soils are a heavy clay loam, a sandy loam, and a sand, approximately 11 per cent of the project being made up of sandy soils. The farm unit in most instances is 80 acres. A few farms are smaller than this and a few somewhat larger.

As is generally true in the reclamation of arid lands by irrigation, alfalfa is one of the principal crops produced on the Minidoka project. This crop is important both because its growth increases the productivity of the soil and because of its value in live-stock production. Other important crops grown on the project are grains, sugar beets, and potatoes. In 1916 crops were harvested from approximately 80,000 acres on 1,849 farms. Alfalfa hay was produced on 37,300 acres and clover hay on 880 acres, the areas devoted to these two crops being about 47 per cent of the total cropped area of the project. About 20,000 acres, or 25 per cent of the cropped area, were devoted to grain crops, chiefly wheat, oats, and barley. These hay and grain crops in ordinary times can be utilized most advantageously when fed to live stock. The 8,666 acres of pasture on the project in 1916, together with the acreage in alfalfa and grains, amounted to more than 80 per cent of the total cropped acreage. Thus, the importance of establishing live-stock industries on the project is evident. Not only have the direct results of live-stock farming proved profitable, but the benefits in the way of soil improvement have been marked. Almost without exception the farms that produced maximum crop returns in 1916 are those where live stock is kept and fed. There are individual instances of crop-yield increases as great as 60 per cent resulting from a single application of manure to the land.

Because of these facts the interest in all kinds of live stock is great, and the live-stock population has increased rapidly during recent years. Table I, which has been compiled from data furnished by the United States Reclamation Service, shows the number of live stock on the project at the beginning and at the close of the year 1916.

Owing to the unusually high prices of grain it was found profitable to sell spring pigs during the summer of 1916 as stock hogs and serum hogs. For this reason, the swine population decreased materially during the year, and a large proportion of the hogs on the farms in December were breeding stock.

TABLE I.—*Live stock on farms on the Minidoka Reclamation Project in 1916.*

| Item.             | Jan. 1. | Dec. 31. | Increase.        |
|-------------------|---------|----------|------------------|
|                   |         |          | <i>Per cent.</i> |
| Horses.....       | 6,557   | 7,174    | 9.5              |
| Dairy cattle..... | 6,902   | 7,314    | 6.0              |
| Beef cattle.....  | 1,220   | 2,304    | 89.0             |
| Hogs.....         | 42,933  | 23,610   | -46.2            |
| Sheep.....        | 16,748  | 21,029   | 24.0             |

All kinds of live stock are proving profitable on the project, and sheep are becoming particularly popular. The high altitude and the dry climate are well adapted to the production of sheep, which in this section have been remarkably free from internal parasites and diseases. Sheep have been found useful in checking the growth of weeds on ditch banks and in fence rows, and they are also relatively easy to care for, especially during the irrigation season when the farmers are busy with other work.

#### HISTORY AND PRESENT STATUS OF THE SHEEP INDUSTRY ON THE MINIDOKA PROJECT.

##### RELATIONSHIP OF FARM SHEEP PRODUCTION TO THE RANGE SHEEP INDUSTRY.

In the early years of the development of the Minidoka project sheep were kept on very few farms. As the project produced large quantities of alfalfa hay and was situated in the midst of extensive grazing areas, it soon became the winter feeding ground of large numbers of range stock, chiefly sheep. The number of sheep wintered on the project during recent years has varied from 60,000 to 195,000. Permanent headquarters for range sheepmen have been established on a number of farms, where lambing sheds have been built and large quantities of hay fed. The range sheep are used extensively in cleaning up hay and grain fields after harvest, as shown in figure 1.

For a long time there was a belief that irrigation farmers could not compete with the men on the ranges in the production of either wool or mutton. The fallacy of this belief, however, has long been shown by successful farm sheep producers. Because of the hazards of the range sheep business and of the difficulties resulting from settlement by dry farmers of areas formerly used as grazing lands, the rangemen in many sections are coming to favor sheep production on farms. As the difficulties of range sheep production increase and with increasing demands for wool and mutton, the possibilities for producing sheep on irrigated farms should become increasingly attractive.

Under certain conditions, particularly where irrigated pastures have not been successfully developed, the ewes from several different farms are sometimes combined into a cooperative band and sent



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FIG. 1.—A band of sheep grazing on the aftermath in hay and grain fields on the Minidoka Reclamation Project. Range sheep are used extensively for this purpose and also to consume surplus alfalfa hay produced on the irrigated lands adjacent to the range country.

to the range under the care of a competent herder. Where a good summer range is available this is a desirable arrangement, especially when individual flocks include more than 100 head. It is believed, however, that this practice, while important to a comparatively small number of farmers, is not likely to be generally adopted. One important deterrent to extensive development in this direction is the lack of available range.

There are two features in which the range sheep industry has a definite relationship to the production of sheep on irrigated farms. These features relate to the farm production of pure-bred rams for use on the range and the use by small farmers of orphan and disowned lambs from range herds. Both of these features will be discussed more fully later.

#### SHEEP POPULATION OF THE MINIDOKA PROJECT.

The number of sheep kept on farms on the Minidoka project increased from 3,599 in 1911 to 21,029 in 1916. The highest number in any year previous to 1916 was 19,965, in 1913. During that year the prices of sheep advanced materially, and a large number of farmers on the project sold out, believing that they could restock their farms later at low prices. Since that time, however, the prices have continued to advance, and the sheep population of the project has increased but slowly. In 1916 the 21,029 sheep on the project were kept on 289 farms, the average number per farm being 72. If from the total number the few relatively large bands which are kept on the range a part of the time were eliminated, the average number per farm would be about 50. The farms where sheep are kept are fairly evenly distributed throughout the project, although there is a tendency for them to be grouped in the vicinity of lambing



camps. This grouping is to be explained largely by the fact that the settlers have been quick to adopt the practices which have been found successful by their immediate neighbors, who in these instances are the men who have been in the sheep business longest and hence have established rather elaborate sheep-producing enterprises. Of the 289 farms where sheep were kept in 1916, 133 carried fewer than 10 sheep each; 46 carried from 10 to 20 sheep; 49, from 20 to 50; 23, from 50 to 100; 28, from 100 to 200; and 10 carried more than 200 each. The flocks containing fewer than 10 head are chiefly those where a start is being made in the sheep industry.

#### AGRICULTURAL DIVERSITY OF FARMS PRODUCING SHEEP.

As a rule, the farms where sheep are kept are well improved and have a wide diversity of crops and live stock. Of the 289 farms keeping sheep in 1916, 263 also carried dairy cattle, the average number of dairy stock on these farms being eight head. A total of 253 of the farms carrying sheep also carried hogs, the average number of hogs being 27 head. Of the 289 farms carrying sheep, 61 carried an average of 11 head of beef cattle. A total of 270 of the sheep-producing farms produced alfalfa, 179 produced grain, 88 produced either beets or mangels, and 219 had irrigated pastures. The average areas per farm in these crops were 10 acres of pasture, 27 acres of alfalfa, 17 acres of grain, and 9 acres of root crops.

As the country is new, there are few definite or well-established systems to follow, as is the case in older communities. There is every reason to believe, however, that a diversity of industries on the farm on these irrigation projects is greatly to be desired, and it appears that the farmers producing sheep on the Minidoka project are gradually approaching a system of desirable diversity.

#### METHODS OF SHEEP MANAGEMENT.

##### RELATIONSHIP OF SHEEP PRODUCTION TO OTHER INDUSTRIES ON THE FARM.

The methods whereby sheep are produced on the Minidoka project fall into two classes—those practiced on the majority of sheep farms where the flocks are small and those practiced on a few farms which are either specialized sheep farms or where the major portion of the agricultural activity is directed toward the production of feed for range sheep during the winter. It is to be expected that most of the sheep growers on the project will continue to raise sheep in connection with other agricultural industries rather than as a specialty. Except in special cases, it is doubtful whether sheep should be made the major industry of a farm. On the average farm, a flock of from 20 to 50 ewes can be kept with advantage to the farm and with a profit to the owner. For those who wish to make more of a specialty of sheep production, a flock of from 60 to 100 head is a popular and

desirable size. Such a flock requires special pastures, winter feed yards, and a lambing shed. It is questionable whether in the long average of years it will be desirable to use an entire farm for sheep production, as has been the tendency in a few cases. A flock of 100 ewes will require on the average the entire production of 20 acres of land. A flock of 350 or 400 ewes would require the entire production of an improved 80-acre farm. With one of these large flocks there would be no inexpensive waste feeds and no by-products of other agricultural industries, which are so profitably utilized by sheep on farms where sheep production is not the exclusive industry. The importance of sheep in the utilization of waste materials should receive special emphasis. It is largely through such utilization that the economical production of sheep on irrigated farms is possible. It is important, therefore, that farmers who contemplate engaging in sheep production on these irrigated lands should carefully consider the relationship of sheep to other industries of the farm and should pay special attention to the utilization of waste materials. Of the 289 farms on the project carrying sheep in 1916, only 38 carried more than 100 head each. This indicates the general tendency to keep sheep in relatively small bands, and such a tendency is to be encouraged.

#### FOUNDATION STOCK.

*Getting started.*—There are various methods whereby a farmer can secure a start in the sheep industry on the Minidoka project. Experience here and elsewhere has led to the conclusion that for the inexperienced man the foundation stock should be grades. The successful production of pure-bred stock requires expert knowledge both in the selection of stock and in its management. It is also important to consider that the cost of starting with pure-bred ewes is much greater than that of starting with grade ewes. So far it has been possible for farmers on the project to secure a start in the sheep business by obtaining orphans and disowned lambs from range sheep camps on the project. These lambs usually may be had for the asking. There are numerous instances in which such lambs have been taken from the camps, fed cows' milk, carefully handled during the first few weeks of their lives, and thus become the origin of successful farm flocks. Good results are secured by feeding cows' milk from a bottle with a small rubber nipple attached. Lambs when obtaining their feed by natural methods receive their milk in small quantities at frequent intervals. This should be kept in mind in the early feeding of lambs secured from range bands. The milk should be clean and of uniform temperature, as determined by a thermometer. Farmers who are successful in raising lambs on bottles feed two or three tablespoonfuls of milk every two hours for the first few days and then

gradually increase the quantities of milk and the intervals between feedings. Where a number of lambs are fed from a few bottles, it is convenient to have the vessel holding the milk heated and carried in a receptacle containing hot water, which keeps the milk at the proper temperature, so that it is not too cold when the last few lambs are fed. For a large number of lambs a barrel or tank equipped with a number of rubber nipples at the base is very convenient.

Carelessness in any detail of feeding is likely to result in scours. The lambs should not be given too much. The temperature of the milk should be about 92° F. The bottles and nipples should be kept scrupulously clean. Scours are best overcome by boiling the milk for a few feeds after the trouble appears. Other common remedies successfully employed are the feeding of a small quantity of charred flour or a teaspoonful of lime water in the milk. For severe cases, a tablespoonful of castor oil is given. Boiled milk should not be fed continuously, as it causes constipation.

*Breeds.*—Because of the intimate relationship which has existed between the farm sheep industry on the project and sheep production on the adjacent ranges, the breeds grown on the project are those of the surrounding range. In this section the popular range ewes are grades of the C type Merino and the Rambouillet or the crossbreeds of a long-wool buck (Lincoln or Cotswold) and fine-wool ewes. Some range bands contain three-fourths or more of the long-wool blood. As a rule, however, the range ewe that is most popular is the one carrying from one-half to three-fourths of fine-wool blood and the remainder long-wool blood. While there are some differences of opinion among the rangemen, the method followed by most of them is to use Rambouillet and long-wool bucks to keep the desired proportion of fine-wool and long-wool blood in the range band. The ewe lambs from these matings are kept to replenish the flocks, while the males are marketed as wether lambs. For the ewes which are to produce mutton lambs, black-faced bucks are used, and the entire lamb crop, both male and female, is marketed, usually early in the season.

The difficulties of range sheep production have been so acute in recent years that only the more efficient of the range sheepmen have remained in the business. These men are usually progressive and quick to grasp opportunities for increasing their profits. One result of this is that the bucks now used are practically all pure-bred animals of the best quality obtainable. This has resulted in a strong demand for pure-bred bucks from the Minidoka project and has presented good opportunities to sheep growers on the project.

The production of registered sheep was started on the project by the establishment of a flock of pure-bred Hampshires in 1911. At that time sheepmen were beginning to realize the value of this large



black-faced breed as a first cross on the range ewes for the production of choice early-maturing mutton lambs. The Hampshire flock started at this time was selected and owned by an experienced sheepman, who was an expert judge of sheep; consequently, the flock ranked high as to both type and breeding. As most of the Hampshire flocks at present on the project have descended from this foundation stock, the Hampshires as a whole, both grade and pure bred, are of uniformly good quality. In 1912 several farm flocks of pure-bred and high-grade Lincolns and Cotswolds were established for the purpose of raising rams to sell to the range sheepmen. The farmers who started properly and gave their flocks good care and attention and have become well informed regarding sheep husbandry have been very successful. Their example is being followed by other enterprising farmers.

So far, the Rambouillet breed has not been popular among the farmers. The irrigation farmer quite properly has had in view mutton production as a first consideration. Consequently, mutton breeds—Lincolns, Cotswolds, Hampshires, and Shropshires—are the most popular at present. There is an excellent opportunity, however, for the establishment of pure-bred Rambouillet flocks, chiefly for the production of rams for use in range bands.

The 21,029 sheep on the project at the close of 1916 are classified in Table II, which shows the number of both grades and pure breeds of each of the breeds represented on the project.

TABLE II.—*Breeds of sheep on the Minidoka Reclamation Project in 1916.*

| Breed.              | Number of—   |         |               | Total. |
|---------------------|--------------|---------|---------------|--------|
|                     | Pure breeds. | Grades. | Unclassified. |        |
| Hampshire.....      | 246          | 820     | .....         | 1,066  |
| Shropshire.....     | 0            | 106     | .....         | 106    |
| Cotswold.....       | 209          | 344     | .....         | 553    |
| Lincoln.....        | 300          | 3,353   | .....         | 3,653  |
| Rambouillet.....    | 40           | 444     | .....         | 484    |
| Delaine Merino..... | 0            | 250     | .....         | 250    |
| Mixed breeds.....   | .....        | .....   | 14,917        | 14,917 |
| Total.....          | 795          | 5,317   | 14,917        | 21,029 |

Of the crossbred or range type of sheep kept, there are some flocks that are being graded up. Others are bred so as to maintain the crossbred type, as it is popularly supposed that the ewes of this mixture are hardier and are better mothers than those of straight breeding. Other arguments advanced in favor of crossbreds are that the ewes of this type will yield more wool than the Down breeds and that if a good buck is used good mutton lambs will be produced. There is some justification for these arguments, but it is also true that these flocks can never attain the high standard of individual excellence

that is being reached by grading up through the use of well-selected, pure-bred rams of a chosen breed. With the exception of the case of a few men whose sheep production is carried on on the range as well as on the farms, it is believed that the continuous production of crossbreds is inadvisable.

*Selection of ewes.*—Summer or early fall is the best time for selecting a flock. At this time the breeders are cutting down their flocks for the winter. From many of the range bands good ewes can be purchased at reasonable prices. In selecting, it is important that the desirable type be borne in mind. Essential points indicating good breeding are a feminine head; deep body with good spring of ribs; a wide, level back, carrying out well on the rump; a good fleece, covering the body uniformly; sound teeth; and good udders. Common mistakes made in bands otherwise well selected are the failure to determine the age by looking at the teeth and the overlooking of barren ewes. The age is easily determined by examining the front teeth. Lambs, up to the time of the first shearing, are easily distinguished, usually by general appearance; otherwise by their milk teeth. About the time of the first shearing, the middle pair of milk teeth are replaced by permanent teeth, which are practically twice as broad as the milk teeth. Sheep with four permanent teeth are designated as 2-year-olds, those with six teeth as 3-year-olds, and a full set of eight permanent teeth appears when the sheep is 4 years old. At varying ages, depending on the breed, care, and individuality of the mature sheep, the teeth become spread, and the sheep is called a "spread-mouth;" or a part of the teeth may be lost, and the sheep is called a "broken-mouth;" or all the teeth may be gone, in which case the sheep is called a "gummer." Careful attention should be paid to these points when ewes are being selected.

*Selection of the ram.*—Although most of the farm flocks on the project are grades, the general custom is to breed to a registered ram. Examples of improvement and increased value brought about in range bands by the use of good pure-bred rams are so numerous and so obvious that practically all the farmers breed their ewes to pure-bred males. Generally speaking, grade rams are used only when it is impossible to secure a satisfactory pure bred. The good results of using pure-bred rams on the farms are becoming very marked. As the ram is "more than half the flock," extra care should be used in his selection. Perhaps the most common mistake made in this connection is to overlook the fact that a pedigree in itself is not an absolute guarantee of individual excellence. Purity of breeding, as indicated by the pedigree, is important, and no ram without it should be selected; but in addition to good breeding, the ram should have the desirable individual characteristics of his breed. He should be masculine, healthy, and vigorous. He

should have a wide, deep chest, a good spring of rib, good bone, and carry out uniformly. The fact that all undesirable characteristics of the ram may influence the entire lamb crop should not be lost sight of, but should prompt the farmer to exercise great care to see that the individual selected is uniformly good in all respects.

#### BREEDING PRACTICES.

As the climatic and other conditions of the Minidoka project are favorable to the production of early lambs, it is the common practice to breed for February and early March lambing. As the gestation period of ewes is 147 days, February and early March lambing requires that the ewes be bred in September or early October. It is seldom necessary in this locality that the ewes be "flushed"—fed heavily in order to make them come in heat.

*Breeding mature ewes.*—For the small farm flock of 10 to 25 ewes a ram lamb may be used. In the flocks containing 25 to 60 ewes it is necessary to use an older ram. It is the general practice to allow bucks to run with the ewes during the breeding period, but where a large number of ewes are to be bred to one ram, he is turned with the ewes only in the morning and in the evening. Some flockmasters make a practice of marking the ewe when she is bred, the mark indicating the time of breeding. The same mark can be used throughout the breeding season, provided its location is changed so as to indicate the week during which the ewe was bred. Such marking is convenient at lambing time, when it is desirable to isolate the ewes which are about to lamb. A further use of marking is that, in case the ram is not a sure breeder, it enables the flockmaster to determine early in the season which ewes have failed to conceive. Some sheep growers paint the breast of the ram with a paint that ultimately fades from the wool. By a change in color of the paint used each week the approximate time of lambing is indicated.

*Breeding ewe lambs.*—Owing to the present demand for sheep and the consequent desire on the part of flockmasters to see their flocks increase rapidly, the ewe lambs are sometimes bred. This practice is confined mostly to the Hampshire breed, but it is followed to some extent with the long wools as well. Usually the lambing percentage obtained with ewe lambs ranges from 50 to 60. Ewes which have been bred as lambs are not as large when they are yearlings as ewes which have not been bred early. The difference in size is usually small, however, by the time the ewes are 2 years old. The breeding of ewe lambs can be practiced only in those flocks where the lambs come early and where growth is rapid from the beginning. As size in ewes is a very important consideration, the breeding of ewe lambs is to be regarded as an undesirable practice.



*Care after breeding.*—After breeding, the ewes ordinarily require no special care or feed until winter. If the waste feeds in the fields are sufficient, there is no better practice than to allow the ewes to run in the fields until snow falls. It is important to remember, however, that the effect of inadequate feed may not be readily observed at this season because of the long fleece on the ewes. Methods of feeding ewes during the winter are further discussed in the chapter on feeds and feeding.

*Care of the ram.*—In summer, a small separate pasture is usually provided for the ram. The farm orchard is a convenient and satisfactory place for this purpose. During the breeding season, if there are a large number of ewes to be bred to one ram, he is kept by himself during the day and is fed oats and bran in addition to hay or pasture. The care of the ram in winter is much the same as that for ewes, except that only a few flockmasters feed roots to the ram, and these only sparingly, whereas a large number of sheepmen feed roots to ewes.

#### LAMBING.

Lambing ordinarily occurs in February or early in March. A few days before lambing the ewes are placed in a sheltered yard or shed. The grain rations are greatly reduced. In some cases, when the ewe shows signs of lambing within a day or two, she is placed in a pen by herself. If there are any loose, dirty locks of wool around her udder they should be removed. The ewe is carefully watched but not disturbed. If she has had plenty of exercise and has been well cared for, little trouble should be experienced in lambing.

The lambing period is one of the most important of the year, and successful lambing requires almost constant attention by the herdsman. Occasionally it is necessary to assist the ewe because of a difficult presentation of the lamb, but the chief need is to assist the weak lambs immediately after birth. If the lamb is chilled, it is taken to a room where a fire is kept burning and warmed by blankets and rubbing. A common practice is to dip the chilled lamb into a pail of water as hot as the hand can bear. The lamb is then carefully dried, given a few spoonfuls of its mother's milk, and returned to the ewe. The use of warm blankets is to be preferred to dipping in hot water. Milk, freshly drawn from the mother ewe, should always be given a weak lamb as soon as possible. A tub or half barrel, bedded with straw and containing a jug of hot water covered with a blanket, is a good place for keeping the lambs while they are being warmed and fed. As soon as possible, the lamb should be returned to its mother.

In many cases, particularly with young ewes and those which have been fed a ration of hay only, there is difficulty in inducing the ewe to allow the lamb to nurse. In such a case, the ewe should be held

and the lamb assisted. If the ewe persists in fighting the lamb, it may be necessary to tie her with a small halter or confine her in a stanchion made by driving two stakes in the ground. Some of the permanent sheds on the project have small stanchions provided in the slats of the hayrack along the wall. It is customary to leave the ewe and her lamb in the pen two or three days, until they get to know each other thoroughly and the lamb becomes strong and active. During this period the ewe should be fed but little grain. After the first few days the ewe and the lamb are turned into the larger pens with other ewes and lambs of the same age, or if the weather is favorable they are turned into a dry, sunny, wind-protected yard. A few days later they may be turned into the larger yard with the band.

Special care should be exercised in keeping the lambing sheds and yards clean. It is not sufficient that the lambing quarters be given the customary one cleaning a year. Each pen should be thoroughly cleaned and disinfected before the ewe and her lamb are placed in it. This is a necessary safeguard to the health of the young lamb, particularly with reference to white scours, from which serious losses sometimes result.

#### DOCKING AND CASTRATING.

The lambs are docked and castrated when they are from one to two weeks old. The work is best done in the morning of a clear, bright day. While it is the general practice to castrate and dock at the same time, it is better to do the docking a few days after the castrating, as the shock of two simultaneous operations is severe and is likely to give the lambs a serious setback. Docking is usually done with a sharp knife. From the results secured by the use of hot docking-irons and pinchers in certain sections of Idaho, it appears that this method should be adopted by sheep growers on the Minidoka project. It has been ascertained that lambs docked with a hot



PT55RP

FIG. 2.—Part of a farm flock of sheep on irrigated pasture on the Minidoka Reclamation Project. From 6 to 10 ewes and their lambs can be carried through the summer on an acre of this pasture.

iron average about a pound more in weight a week after docking than lambs which have been docked by the ordinary method and have lost considerable blood. Castrating is done by cutting off the lower third of the scrotum and pulling out the testicles, cords and all.

#### WEANING.

In the pure-bred flocks, or where it is desired to keep the ewe lambs for breeding purposes or for the fall and winter markets, weaning takes place when the lambs are 4 to 5 months old. By separating the lambs from the band and allowing them the run of good pasture, they do as well as if allowed to run with the ewes all summer. In some instances they do better. Moreover, if the ewes are allowed a summer's rest, they will breed earlier and produce a higher percentage of lambs.

A common method of weaning lambs on irrigated pasture is to leave the lambs in the same field but to remove the ewes to poor feed out of sight and hearing of the lambs. At the same time the ram lambs should be separated from the ewe lambs. A few flockmasters wean the lambs gradually, allowing them to be with the ewes for short periods twice each day. This method has some advantages, the chief of which is that the milk of the ewes dries up gradually. However, the practice can be continued too long, two or three days probably being the best time. Whatever method of weaning is pursued, it is necessary to watch the ewes carefully and to draw the milk from the udder in case of congestion.



P75BRP

FIG. 3.—Sheep grazing on a canal bank on the Minidoka Reclamation Project in August, 1916. Used in this way, sheep are helpful in eradicating weed growth, and at the same time they produce mutton and wool at small cost.





P826RP

FIG. 4.—A farm flock of sheep on an alfalfa field in winter, eating mangels fed whole. The feeding of roots in this manner is a common practice on the Minidoka Reclamation Project.

#### FEEDS AND FEEDING.

The feeds for sheep on the Minidoka project may be divided into three general classes: Pastures, waste products, and the feeds used in late fall and winter. While there are some variations in the periods of utilizing the different feeds, in general the irrigated pastures are the basis of summer feeding; the waste products are utilized in late summer and early fall, and hay and grain are fed in the winter.

*Pasturing.*—Irrigated pastures are becoming increasingly popular among sheep growers on the project. Of the 289 farms carrying sheep in 1916, 219 contained pasture, the average pasture area being 10 acres per farm. A part of a farm flock on irrigated pasture is shown in figure 2. There is a variety of pasture mixtures in use. Nearly every pasture, however, contains bluegrass and white clover. Perhaps most of the pastures at present in use were originally seeded to the mixture recommended by the Idaho Agricultural Experiment Station,<sup>1</sup> containing the following, at the rates of seeding in pounds per acre indicated: Kentucky bluegrass, 8 pounds; orchard grass, 5 pounds; smooth brome-grass, 5 pounds; meadow fescue, 4 pounds; timothy, 4 pounds; and white clover, 2 pounds. The total quantity of seed in this mixture is 28 pounds per acre. These special pasture mixtures, which are in general use on the Minidoka project, provide rich feed and are ready early in the season. On these pastures the lambs make such rapid growth that they are ready for market early in June. In 1916, the first shipment of spring lambs was made on May 27, when two carloads left the town of Rupert. These lambs were bought to weigh between 65 and 80 pounds. The best lot in the shipment was a flock of 74, averaging  $73\frac{1}{2}$  pounds each at the loading station. These lambs had been born during the latter part

<sup>1</sup> Welch, J. S. Grass pastures for irrigated lands. Idaho Agr. Exp. Sta. Bull. 80, 15 p., illus. 1914.

of February and had received no grain. Their mothers, however, had received good feed and excellent care. Where the pasture has been well started and properly cared for, on the heavier soils of the project as many as 10 ewes and their lambs are carried on 1 acre for the entire season. The average pastures, however, will not carry so many stock, seven ewes and their lambs being a common carrying capacity. The best results are secured by having the pasture divided into three parts, so that the stock are off the pasture during irrigation and for some time afterwards. Neither horses nor hogs should be allowed in the pasture with the sheep, but excellent results are secured where sheep and cattle graze together. Pure drinking water and salt should be provided at all times. It is desirable, also, that shade be provided in each pasture, as this adds to the comfort and thrift of the animals. When, as the result of overstocking or unfavorable growing weather, the pasture becomes temporarily overgrazed, it should be supplemented by feeding some grain to the lambs. In some instances the ewes become too fat on irrigated pasture, so that they do not breed satisfactorily. This difficulty can be eliminated by turning the ewes into stubble fields or otherwise providing a relatively scanty feed for a short time.

There are occasionally instances in which it seems advisable to pasture clover and alfalfa, although the practice is somewhat hazardous on account of bloat. There are many theories as to the best method of preventing bloat. The safest practice appears to be to have the sheep well filled with hay or other feed before they are turned on the alfalfa and clover pasture. Some farmers maintain that if no shade is provided bloat is less likely to occur. They argue that when shade is provided the sheep remain in the shade too long on hot days and then consume large quantities of succulent feed in a



P932RP

FIG. 5.—Typical shed and winter yards for a farm flock of sheep on the Minidoka Reclamation Project. A common and satisfactory practice, is to have the closed shed used for lambing face to the south, and the open shed, for general uses, face the east.



P923RP

FIG. 6.—A popular type of lambing shed on the Minidoka Reclamation Project, having a large sliding door at each end and large open windows on the south side. Feeding racks of the box type are illustrated at the left, and the winter yards are shown in the foreground.

short time. The use of alfalfa and clover as sheep pasture must be regarded as dangerous. Experienced sheepmen make the statement that unless a flockmaster is willing to risk a loss of 10 per cent he should not attempt to pasture his flock on alfalfa during the entire season. A few sheepmen cut and cock the third cutting of alfalfa and then turn the sheep into the field. So far, no unfavorable results have been reported.

*Utilization of waste products.*—The sheep is a very efficient animal in utilizing certain waste products on the irrigated farm. On all these farms there is much waste feed, including weeds and native grasses on ditch banks and in fence rows, the waste hay and aftermath in hay fields, grain and weeds in stubble fields, and the beet tops left after the sugar-beet harvest. As the growth of the irrigated pasture crops begins to diminish, these waste materials begin to become available, so that the sheep are gradually moved from the pastures to the fields, ditch banks, etc., where, in ordinary seasons, they are well fed until December. The sheep oftentimes can be used for temporary periods in summer in cleaning up weeds from ditch banks (as illustrated in figure 3) and other similar places on and about the farm. By these methods, the sheep assist in keeping down undesirable vegetative growth and in removing waste material, at the same time producing valuable mutton and wool.

*Late fall and winter feeding.*—After the first snowfall, which usually comes in December, it is necessary to feed the flock. It is a desirable practice to allow the sheep the run of the fields during the winter feeding period so as to avoid the difficulties resulting from the lack of exercise. Approximately half the flockmasters on the project feed only hay during the winter. About one-fourth of the sheep growers produce and feed mangels, beets, or beet pulp, and about one-fourth feed



a grain ration. A few flockmasters feed both roots and grain. There are no silos on the project at present, but elsewhere in southern Idaho corn silage is fed to the breeding flocks with excellent results. As it is popularly believed that the excessive feeding of roots may result in the productin of soft, flabby lambs, the quantity of roots fed during the winter is not large, from 2 to 4 pounds per sheep being the daily allowance. Roots commonly are fed whole and in the field, as illustrated in figure 4. In some instances where grain is used, grain feeding begins a month or six weeks before lambing. Other flockmasters do not feed grain until after lambing time. There is, perhaps, no better grain ration to supplement alfalfa than a mixture consisting of two parts oats and one part bran. A half pound to a pound of this mixture per head each day is sufficient. Unthrashed sheaf oats is a popular and desirable feed to use in connection with alfalfa. The practice of feeding some supplement with alfalfa is rapidly gaining in popularity. Where such feeding is not practiced, it is frequently found that young ewes refuse to own their lambs and that neither young nor old ewes produce sufficient milk to feed the lambs properly. It is important to provide the flock with fresh water and salt at all times. The practice of forcing the flocks to drink from stagnant ponds or dirty drinking troughs is to be condemned.

#### BUILDINGS AND EQUIPMENT.

Except at lambing time, shelter is not absolutely necessary, although open sheds and windbreaks are desirable, as there is need for protection against west winds. A dry yard with an open shed or windbreak or with an open shed and a closed lambing shed joined

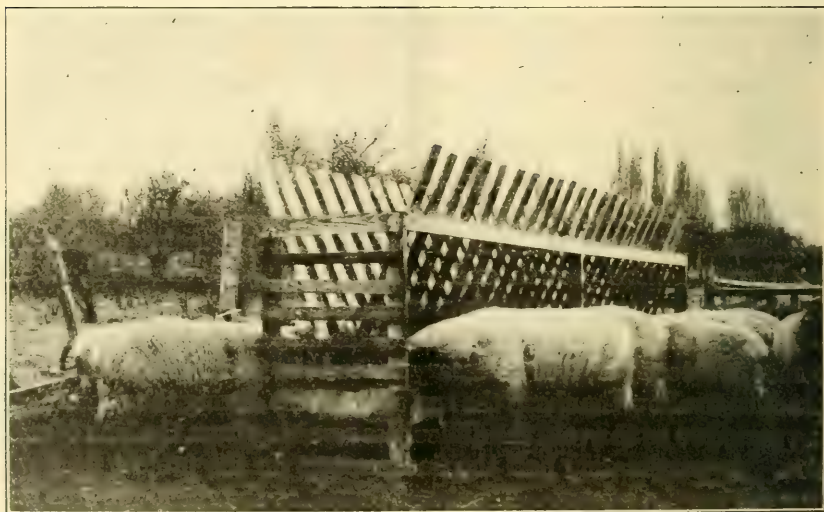


FIG. 7.—A popular type of combination hay and grain rack for feeding sheep.

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together in the shape of an L, so as to give protection from the north and west winds, is desirable. A typical L-shaped shed is illustrated in figure 5.

*Lambing sheds.*—There are several types of good lambing sheds in use on the project. One of the most popular is a shed 18 or 20 feet wide, extending east and west. This shed is 5 feet high at the eaves on the north and 6 feet high on the south. Large open windows, which can be closed with muslin or canvas, are placed in the south side. Large sliding doors are provided in both ends. Sheds of this type are permanent and are of value during the entire winter. The east door may be left open, so that the sheep may enter or leave the shed at will. A shed of this type is shown in figure 6. Other types of sheds are open, facing either the east or south; while others are partly open and partly closed, and one popular type has a skeleton roof open to the east or south, which is covered with canvas when the shed is in use. Many successful flockmasters house their flocks in tent houses or in straw sheds. When properly made, these are entirely satisfactory, and if the necessary care is given a high percentage of lambs is saved.

There is a too common tendency to make sheds too warm, too dark, and too poorly ventilated. Dryness, sunlight, and good ventilation without drafts are essential to the comfort of the flock. Where sheds are built with insufficient ventilation, catarrh, pneumonia, and other similar ailments are common.

A typical interior arrangement of sheds extending east and west and 20 feet wide is as follows: On the north side there are large pens, 13 feet wide and from 15 to 25 feet long. The side of the shed forms one side of these pens, and panels form the other sides. Partitions between the pens are made in the form of hayracks or combination hay and grain racks, so that the ends of the pens contain the feed. Water troughs are also provided. On the south side of the shed there is a row of small individual pens. These commonly are made of panels 4 feet long and 3 feet high, two of which are hinged together so as to form a half pen. These two, placed in a corner of the shed, make a complete pen 4 feet square. Additional individual pens adjoining these are made by the use of similar hinged panels provided with hooks for setting up and taking down easily. When not in use the panels are folded together and piled in one corner of the shed. Some of the large pens on the north side are used by the ewes which are within a week of lambing, and others are occupied by ewes with lambs a few days old. Just before or immediately after lambing the ewe is placed in one of the individual pens and kept there until the lamb is 2 or 3 days old. Another common arrangement is to have the entire shed filled with these individual pens. This is undoubtedly a good arrangement, but it entails

more labor in feeding than the one here described, so that it seems preferable to keep some of the ewes in larger pens. In all well-planned sheds a room is provided in one end for the shepherd. A stove is placed in this room, so as to keep the room warm during the lambing season.

*Racks and troughs.*—There are two common types of hayracks. One is a V-shaped rack made of 1 by 4 inch pieces alternating at the base or 1 by 2 inch pieces 4 inches apart. By the use of a 10-inch board for the base these racks are often made into a combination grain and hay rack, as illustrated in figure 7. The base also catches much of the chaff and the leaves that break off from the hay. An objection to this type of rack is that some of the chaff falling from above gets into the sheep's wool. This objection can be overcome largely by the use of 1 by 12 inch boards put together lengthwise over the upper part of the rack. Another objection to the combination rack and trough is that the troughs are not usually kept clean. The other popular type of rack is a long, rectangular one, 2 feet wide and 2½ feet high. The baseboards are 16 inches high. Above these is an 8-inch space through which the sheep insert their heads, and above this is a 6-inch board. If desired, a bottom is easily provided. This type of rack is used commonly for feeding chopped hay, although the self-feeder type is becoming popular. For the best results separate grain troughs are provided. The sheltered board-bottom trough, swinging on bolts in a frame so it can be turned and cleaned easily, is very satisfactory. When it is desired to feed the lambs by themselves, creeps can be provided to admit them to the troughs while excluding the ewes. There is a wide choice of types of water troughs. The chief consideration in this connection is that the trough be so arranged that the water can be kept clean.

#### DISEASES, PESTS, AND MINOR AILMENTS.

There is unfortunately a common belief that little can be done for a sheep that becomes sick or unthrifty. In many cases, particularly in pure-bred flocks and in well-managed range bands, the fallacy of this belief has been shown. The flockmaster should not hesitate to secure the services of a competent veterinarian at the first indications of unthriftiness or disease. A brief discussion of pests, diseases, and minor ailments which have been found or may occur on the Minidoka project is given below.

*Dogs and coyotes.*—On farms near the open range the coyote is still a menace. On these farms and near the towns the dog also does considerable damage. For some reason the Idaho flockmaster has been loath to believe that dogs kill sheep, coyotes commonly being blamed for the work of dogs. So long as dogs are allowed to run at large and while coyotes are as prevalent as at present, some



kind of protection must be provided for the sheep. High fences which are proof against coyotes or dogs furnish effective protection. In some parts of the project it is necessary to confine the flock in a good corral during the night. It is important that present and prospective sheep growers have clearly in mind the possibility of damage by dogs. In certain sections of the United States the damage from this source has become serious, and it is therefore recommended that irrigation farmers provide ample protection for their sheep.

*External parasites.*—The common external parasites of sheep are lice, ticks, and the scab mite. Of the three, the scab mite is the most important. This mite burrows under the skin of the sheep and causes the formation of scabs. Suspected cases should be reported to the State or Federal inspectors, who will examine the sheep and if scab is present superintend the dipping.<sup>1</sup> The sheep louse is rarely found on the Minidoka project, but ticks are very numerous. By sucking the blood of the sheep, these pests reduce the animal's vitality, interfere seriously with the thriftiness of the flock, and retard the growth of lambs. In view of the serious damage caused by these parasites, it is surprising to note that on many farms the flocks are allowed to go unprotected year after year. Some of the farms are now equipped with dipping vats, made of wood, galvanized iron, or concrete, in which the flock may be dipped. These vats are 16 inches wide at the bottom, 24 inches wide at the top, 4 feet deep, and 5 feet long at the bottom and 10 feet long at the top, with an inclined bottom at one end. Any of the standard sheep dips used according to directions will destroy both lice and ticks. It is best to dip the flock just after shearing. If any sheep are added to the flock during the summer or if the presence of ticks is noticed, the flock should be dipped again in the fall, as the ticks increase rapidly during the winter.

*Internal parasites.*—Important internal parasites are stomach worms and small and large tapeworms. Although the stomach worm has not been reported on the project, it is believed that its absence is due merely to the fact that it has not yet been introduced and not to any local conditions unfavorable to the worm. In some sections of southern Idaho stomach worms are becoming common. A satisfactory method of treatment for this parasite is to drench the sheep with a solution made by dissolving 1 pound of copper sulphate (blue vitriol) in 10 gallons of water, 1 dram of the copper sulphate being sufficient to treat one sheep. Gasoline, administered in doses of from 1 to 3 drams in linseed oil or milk, is another effective remedy in general use. To be effective, these treatments

<sup>1</sup> A detailed discussion of sheep scab is given in United States Department of Agriculture Farmers' Bulletin 713, entitled "Sheep Scab."

must be repeated. The appearance of stomach worms sometimes can be prevented to some extent by the use of copperas or turpentine, which may be fed with salt. Equal weights of copperas and salt may be used, or the salt may be saturated with turpentine.

The small tapeworm<sup>1</sup> is at present the most serious internal parasite on the project. This worm is usually found to be 4 or 5 inches in length, although a few reach a length of 6 inches. Usually it produces no bad effect until the sheep are changed from green feed to dry feed in the fall. At this time the worms enter the sheep's bile duct and cause death. While the worms are still in the intestines the same treatments that are valuable in expelling stomach worms are effective in expelling the small tapeworm, but no known treatment is effective after the tapeworms enter the bile duct. The life history of this parasite is not well understood. So far, the worm has been found on the project only in those flocks that have been kept on certain summer ranges.

The large tapeworm<sup>2</sup> is not common on the project. Where this worm is present it is easily removed from the mature sheep through the administration of a dose of 2 drams of extract of male shield-fern in half a cup of milk. Lambs are given somewhat smaller doses. The treatment is followed two hours later by a dose of castor oil.

*Foot-rot.*—Fortunately foot-rot has been extremely rare on the project. So far as known, it has not occurred where the yards used in winter have been kept dry and clean and where the sheep have not been grazed in wet pastures in summer. A remedy which is popular in Idaho consists of the application to the affected parts every four days of a solution of 1 pound of copper sulphate in 1 gallon of vinegar.

*Digestive disorders.*—The three principal digestive disorders among sheep on the project are scours, constipation, and bloat. Sheep frequently suffer from scours shortly after they are turned on fields to clean up beet tops. The difficulty may be prevented if the sheep are given some feed in addition to the beet tops. This feed may be hay, or it may be provided through giving the sheep access to stubble fields in connection with the beet-top pasture. Some farmers overcome the difficulty by pasturing the sheep in other fields and hauling the beet tops to them. This practice is not common, however, because of its labor requirements. The remedy usually applied is a teaspoonful of ginger in a cup of warm water. In severe cases, the remedy is 1 teaspoonful of laudanum administered in milk to mature sheep and somewhat smaller doses for lambs. Constipation ordinarily occurs among the older, broken-mouthed sheep in the winter in the flocks which are fed hay alone. A dose of Epsom salts or castor

<sup>1</sup> *Taenia fimbriata*.

<sup>2</sup> *Taenia expansa*.

oil, followed by a change of feed, is the only remedy that has been found generally effective. Bloat occurs rather commonly. One of the best remedies is to administer from a pint to a quart of cows' milk, freshly drawn and warm. A half-pint of warm, sweet cream has also proved effective, as have the common remedies used in cases of bloat in cattle. Tapping should be attempted only as a last resort, as it is seldom that an animal so treated thrives afterwards.

*Miscellaneous ailments.*—There are a number of miscellaneous ailments which cause some damage. Catarrh, or "sniffles," is common among the open-wooled breeds when the animals are exposed to the rains. It is also common in flocks that are kept in warm, poorly ventilated stables or that are forced to sleep in snow or in wet, muddy yards. Garget, or caked udder, is usually caused by the congestion of milk in the udder, but it may result from chilling, from bruising the udder, or from improper feeding. There is also a contagious form, which, however, has never appeared on the project. If the udder is carefully attended to before lambing time and again when the lambs are weaned, garget seldom occurs. Effective remedies to use are bathing the udder with water as hot as the hand can bear, massage, and applying a mixture of lard and turpentine.

Lip and leg ulceration is occasionally brought in from the outside. By prompt treatment and rigid quarantine, it so far has been prevented from becoming widespread in this section. Usually the attention is first attracted by lameness or perhaps by scabs on the nose and lips of the affected animal, from which a greenish pus is exuded. This gets on the ground and feed and in the water troughs and thus spreads the infection throughout the flock. Affected animals lose flesh rapidly, and if treatment is not given heavy losses may result. It is necessary to resort to hand dressing, in which the scabs are removed and the affected parts treated with a solution of nitric acid, 1 part of the acid to from 5 to 9 parts of water.

One other difficulty which occasionally occurs is gravel stones (calculi). This difficulty usually occurs in rams and wethers that are ranged on beet tops or fed beets or mangels heavily. Ewes are not so affected. As no effective remedy is known, it is best, in feeding male sheep, to restrict the quantities of the feeds mentioned.

Broken pasterns and crippled or deformed feet are commonly caused by allowing the hoofs to become overgrown. This can be prevented by trimming the hoofs once or twice a year. Pruning shears or a sharp knife may be used for this work.

#### SHEARING.

The month of May is the popular time for shearing the farm flock. Earlier shearing permits the fleece to make such a growth by July and August that the thrift of the animals during these warm



months is interfered with. If shearing is delayed later than May, the sheep may shed a part of the wool and the fleece become ragged. When shearing, a clean floor should be provided. The wool should be clipped off close to the body, and as smoothly as possible, all the fleece being kept in one piece. The tag wool should then be removed and the fleece neatly rolled with the flesh side out and tied with paper twine. It is advantageous to sack the wool of the rams and black sheep separately. The tag wool should be sacked separately and labeled.<sup>1</sup> In some of the long-wool flocks, where lambs have come early and the shearing is done late, the lambs are sheared. This undoubtedly is advantageous to the lambs, as they are thriftier, more active, and attain greater size. The practice, however, has a disadvantage at the time the lambs are sold, as, because of the appearance of the wool, the buyer is likely to mistake the lambs for yearlings and quote prices accordingly. After the shearing is completed, the sheep should be dipped if lice or ticks are present in the flock.

#### MARKETING.

*Marketing lambs.*—The first early lambs that have received good care are marketed late in May or in June. Practically all are shipped to the large markets of the Middle West, chiefly Omaha. The freight rate from the Minidoka project to Omaha is 68 cents per hundred-weight on a minimum of 23,000 pounds to the double-deck car.

Marketing methods have not yet become well established. There is some informal cooperative shipping in a few districts where carload lots occasionally are sent to market by groups of neighboring farmers. This is a practice that could well be increased, as marketing from the small bands is sometimes difficult. If sold before other shipments from farms or from the ranges arrive, small numbers of lambs must be held by the buyer until a full carload has been secured. This is an expensive system and results in a wide variation in price, even for lambs of the same market type. Shipments of farm lambs usually are made in connection with shipments from the ranges. Table III shows the number of cars of sheep and lambs shipped from the project each month from May 1 to December 31, 1916. Included in these shipments, approximately 5,500 head of lambs were marketed from the farms.

*Marketing wool.*—As there is no wool exchange or other public market on the project, each individual owner ordinarily attends to the marketing of his own wool. By shearing time most of the range sheep have been taken to the ranges. The clip from a large number of

<sup>1</sup> Useful detailed information regarding shearing, classing, and marketing wool has been given by Marshall and Heller. (Marshall, F. R., and Heller, L. L. The woolgrower and the wool trade. U. S. Dept. Agr. Bul. 206, 32 pp., 1 fig., 11 pls. 1915.)

these is pooled and sold cooperatively. As yet the owners of small farm flocks have not adopted the cooperative method, but sell independently to a local or a traveling buyer. As a shipment of wool bought from a large number of men varies greatly as to the grade and quality, as well as to the methods of classifying and packing, the price must necessarily be lower than if uniform systems of shearing, grading, classifying, and tying were used and the combined clips from the different farms pooled and sold together. Wool is bought in the field at any time from February until after shearing. Table IV shows the prices received for a number of representative carload shipments of wool loaded at project points in 1915 and 1916.

TABLE III.—*Shipments of sheep and lambs from the Minidoka Reclamation Project from May 1 to December 31, 1916.*

| Month.         | Number of cars. | Range in weight. | Average weight. | Prices f. o. b. project points. |
|----------------|-----------------|------------------|-----------------|---------------------------------|
|                |                 | <i>Pounds.</i>   | <i>Pounds.</i>  | <i>Per cwt.</i>                 |
| May.....       | 4               | 60 to 74         | 68              | \$9.00 to \$9.50                |
| June.....      | 8               | 64 to 108        | 77              | 6.50 to 9.00                    |
| July.....      | 13              | 60 to 95         | 68              | 7.50 to 8.25                    |
| August.....    | 13              | 50 to 90         | 74              | 7.00 to 8.50                    |
| September..... | 70              | 65 to 105        | 93              | 7.00 to 7.75                    |
| October.....   | 22              | 70 to 98         | 90              | 6.00 to 8.50                    |
| November.....  | 35              | 68 to 97         | 82              | 8.00 to 9.25                    |
| December.....  | 60              | 74 to 107        | 84              | 8.00 to 9.50                    |
| Total.....     | 225             | 50 to 108        | .....           | 6.00 to 9.50                    |

TABLE IV.—*Range of prices received for representative shipments of wool on the Minidoka Reclamation Project in 1915 and 1916.*

| Month.     | 1915            |                   | 1916            |                   |
|------------|-----------------|-------------------|-----------------|-------------------|
|            | Number of cars. | Prices per pound. | Number of cars. | Prices per pound. |
|            |                 | <i>Cents.</i>     |                 | <i>Cents.</i>     |
| April..... | 2               | 23 to 24          | 3               | 28 to 29          |
| May.....   | 5               | 17 to 24½         | 1               | 25 to 30          |
| June.....  | 3               | 22½ to 26         | 2               | 28 to 32          |

There is need for much improvement in the methods now practiced in marketing both lambs and wool, and it is expected that numerous improvements will be made as the industry develops.

#### FUTURE DEVELOPMENT OF THE INDUSTRY.

Judging by the demand for information regarding the problems of sheep production on the Minidoka project during the past year, it is probable that the industry will experience a marked expansion. Many farmers who formerly were apathetic have become interested and are seeking information. All the factors influencing the extension of the farm sheep industry on the project are favorable. The farmers

are becoming increasingly interested and better informed; the climatic and agricultural conditions furnish excellent opportunities for sheep production, and there is every reason to believe that prices for both mutton and wool will continue to be high. In developing the industry it is important to keep in mind the relationship of sheep production to the other industries of the farm and to the range sheep industry. It is desirable that conservative methods be followed. The importance of community action should not be overlooked, and serious efforts should be made to stabilize the industry.

#### CONSERVATIVE PRACTICES.

For the man who is inexperienced in sheep husbandry it is undoubtedly desirable that the start should be made in a small way and with grade ewes. If he desires, he can later work gradually into pure-breds. In this way the common mistakes of the beginner are made with relatively inexpensive grade sheep, and by the time the pure-breds are secured the requirements of good care and management can have been learned. The most successful breeders of pure-bred sheep at present are for the most part those who gained their early experience with bands of grades or with range sheep. The success of the registered flock will depend entirely upon the owner. Before securing pure-bred stock the flockmaster should be prepared to give the flock every advantage. By the time the necessary experience and knowledge have been gained through handling a flock of grade sheep the shepherd will have learned whether or not the work is to his liking and whether he will be willing to devote the care and attention necessary to success with pure-breds. Such procedure requires time, but it seems to be the only safe method to follow.

#### RELATIONSHIP OF SHEEP PRODUCTION TO OTHER INDUSTRIES.

There are but few farms on the project where a small flock of sheep can not be kept with profit. It is believed that the absence of sheep from many farms is due to ignorance of the farm owners regarding the possibilities of sheep production. Another reason is a lack of definite knowledge of the lore of sheep husbandry. It must be admitted that some men can never make a success with sheep. It is questionable whether the hasty, impatient, quick-tempered, or careless man can succeed in any live-stock industry, particularly with sheep or dairy cattle; but to the man who has an inherent interest in farm animals and to whom it is a pleasure to see stock kept thrifty, comfortable, and contented, the small farm flock of sheep is a source of both profit and pleasure. The production of such flocks fits in well with the other industries of the irrigated farm in this section, as already has been pointed out. It is necessary, however, for the farmer to adjust his sheep-production activities to his other farming operations,



so that his farm will not become overstocked on the one hand or his sheep receive too little attention on the other. The proper relationship of sheep production to other industries on the farm can be developed only with practical experience, and this is best gained through the patient practice of conservative methods. It is important, also, that the sheep grower keep in mind his relationship to the more extensive sheep producer who makes use of the range lands. Possibilities of mutually profitable cooperation between these two classes of producers already have been pointed out.

#### COMMUNITY COOPERATION.

During the last few years the demand for sheep and wool has been so strong as to make it appear that community cooperation in the various enterprises of sheep production is not necessary. Perhaps this explains the absence of extensive cooperative activities in sheep production on the Minidoka project. It has been noted in other sections of Idaho, however, that sheep growers are cooperating in both production and marketing and that the results are more satisfactory than those secured by farmers on the Minidoka project. There are good opportunities for community cooperation in such matters as securing breeding stock, purchasing supplies, marketing wool and mutton, and the general dissemination of useful information. The importance of cooperation in these matters will be increasingly apparent as farm sheep production in the western United States increases, and it would be advantageous for communities already engaged in the industry to begin early to develop cooperative relationships.

#### STABILIZING THE INDUSTRY.

It has been pointed out repeatedly that the development of satisfactory methods of management requires experience. The successful establishment of farm sheep production is possible only through the persistent application of the best methods of management. The experience of the farmers on the Minidoka project during the last five years has shown clearly the undesirability of getting into or out of the sheep business suddenly because of market fluctuations. The men who have remained in the business are demonstrating that the industry will be permanent on most farms. On almost half the farms the care, attention, and general methods of management are far above the average for other sections of southern Idaho and are of a character which insures success. The natural advantages of the high altitude, the dry climate, the many clear days, the abundance of irrigated pasture with other cheap feeds, and the short winter feeding period are all favorable to the development of the industry. Good care, a study of the habits of the flock, and an earnest effort to satisfy

its natural requirements, together with a desire to keep the animals in a thrifty and contented condition, are bringing success to many men whose problems and methods have been investigated. When all the facts are considered, including the local and general economic conditions, it seems certain that, if properly carried on, sheep production on the farms of the Minidoka project is potentially one of the most profitable agricultural industries. The extent to which the industry will realize its possibilities will depend very largely upon the exercise of persistent endeavor, through which the necessary stability can be secured.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 574

Joint Contribution from the Bureau of Plant Industry,  
WM. A. TAYLOR, Chief, and the Bureau of Markets,  
CHARLES J. BRAND, Chief



Washington, D. C.



September 28, 1917

# THE CONVERSION OF THE WEIGHTS OF MECHANICAL SEPARATIONS OF CORN, WHEAT, AND OTHER GRAINS INTO PERCENTAGES.<sup>1</sup>

By E. G. BOERNER, *Grain Supervisor.*

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## METHOD OF OBTAINING REPRESENTATIVE SAMPLES.

The rules and regulations for the enforcement of the United States Grain Standards Act prescribe a definite procedure for securing a representative sample upon which the grade of any particular lot or parcel of shelled corn or wheat is to be based.

The rules provide that the original sample must be not less than 2 quarts in quantity, of which approximately  $1\frac{1}{2}$  pints must be placed in an air-tight container and the remainder inclosed in a cloth sack. The portion in the container is intended for the determination of the percentage of moisture, and this portion should be used for that test only. The remainder of the sample, contained in a cloth bag, will approximate  $2\frac{1}{2}$  pints, and this portion is to be used for the remaining determinations, which for wheat include color, wheat of other classes, damaged kernels, inseparable material, and dockage, and for corn include color, damaged corn (not including heat damage), heat-damaged corn, and foreign material and cracked corn. The grades specify maximum and minimum percentages for the factors mentioned, and these percentages are to be determined by weight.

<sup>1</sup> The work covered by this bulletin was begun under the direction of Dr. J. W. T. Duvel, of the Office of Grain Standardization of the Bureau of Plant Industry. Since Aug. 18, 1916, the grain-standardization work of the Department of Agriculture has been administered jointly by the Bureau of Markets and the Bureau of Plant Industry in connection with the administration of the United States Grain Standards Act.



Because of the time involved, it is impracticable to make the mechanical separations on the entire  $2\frac{1}{2}$  or more pints, and it therefore becomes necessary, in most cases at least, to divide the sample in order to obtain a smaller representative portion for the determination of the factors mentioned.

Experiments have shown that the sample upon which the determinations for the factors mentioned are based should be approxi-

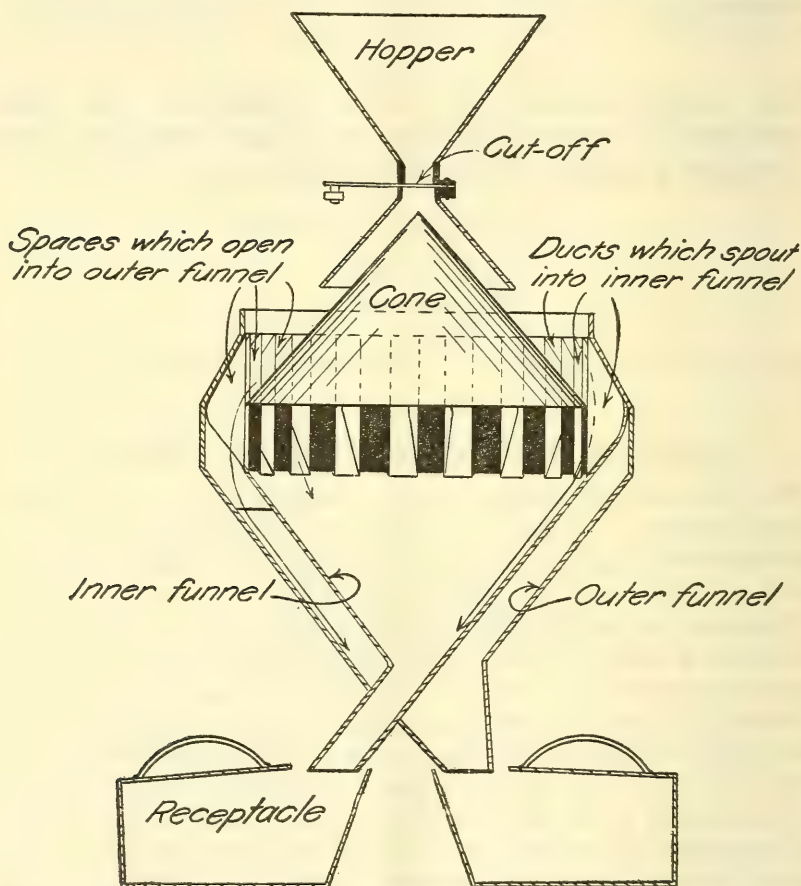


FIG. 1.—A vertical cross section of the sampling device, showing the paths taken by the material in passing from the hopper to the containers.

mately 40 grams in weight for wheat and approximately 250 grams in weight for corn. After the mechanical separations and weighings have been made, mathematical calculations are involved in order to convert these weights into terms of percentage, and the accompanying tables enable the analyst to accomplish these results without any calculations.

## DIRECTIONS FOR USING THE TABLES.

Table I shows the percentage equivalents for separations weighing from 0.1 to 20 grams taken from samples weighing from 25 to 65 grams, inclusive, which covers the entire range of maximum and minimum limits of color, wheat of other classes, damaged kernels, and inseparable impurities specified in the numerical grades of the United States standards for wheat.

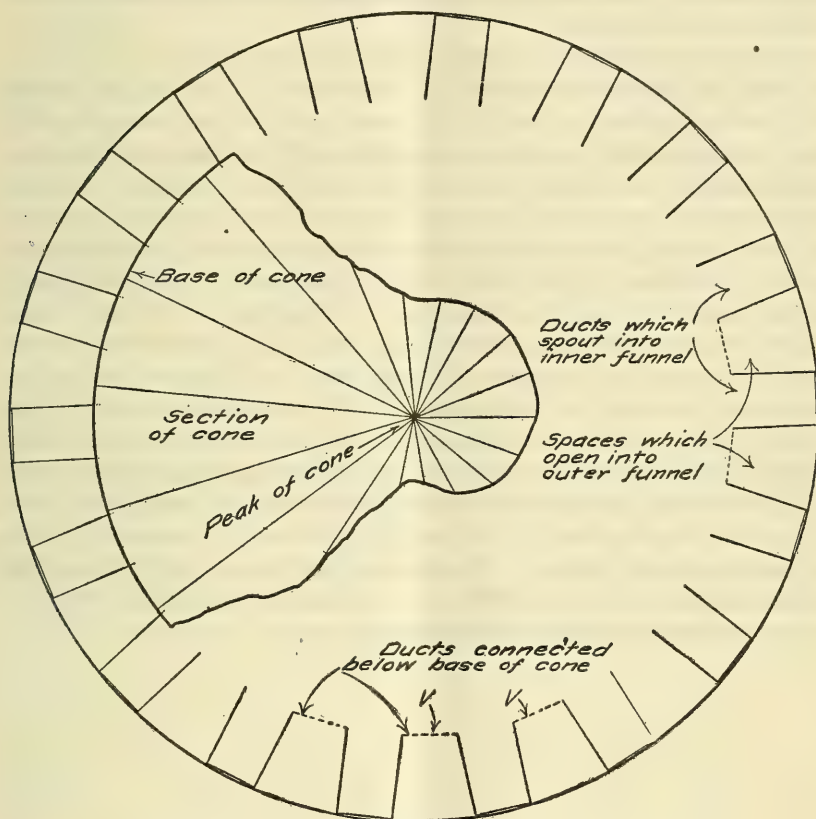


FIG. 2.—Cross section of the sampling device at the base of the cone.

Table II shows percentage equivalents for separations weighing from 0.1 to 40 grams taken from samples weighing from 240 to 260 grams, inclusive, which covers the entire range of maximum limits of corn of other colors, damage, heat damage, and foreign material and cracked corn specified in the numerical grades of the United States standards for shelled corn.

The solution of the following problem will illustrate the use of the table:

*Problem.*—A sample weighing 240 grams contains 8 grams of damaged corn. What is the percentage of damaged corn contained in the sample?

Referring to Table II (p. 14), follow down the first column to the figure 8.0 (the weight of the separation of damaged corn in grams). The figure opposite (in the second column, with heading 240) is found to be 3.3, which is the correct percentage expressed in the nearest tenth of 1 per cent.

The use of the table will save time in converting the separations into terms of percentages of the whole sample analyzed, and its careful use will prevent errors which often occur in the mathematical calculations involved.

In this connection it is highly essential that extreme care should be taken to preserve accurately the character of the original sample when reducing the original  $2\frac{1}{2}$  or more pints taken from the bulk grain to the smaller sample of approximately 40 grams for wheat or approximately 250 grams for corn for analytical purposes. Experiments have shown that it is almost impossible to divide a large sample into smaller portions and at the same time retain the correct proportion of damage, dirt, color, etc., in the smaller sample unless a device similar to the one described in Bulletin 287 of the United States Department of Agriculture is used. This apparatus was devised to meet the demands of grain and seed dealers, as well as laboratory workers, for securing a reliable grain or seed sample from a larger portion of the material to be examined, analyzed, or graded. Figure 1 shows a vertical cross section of the sampling device, while figure 2 shows a cross section of this device at the base of the cone. A detailed description of this sampling device is contained in the before-mentioned bulletin. This device has been covered by a public-service patent (No. 1,160,036), and anyone in the United States is free to make and use it without the payment of a royalty.





TABLE I.—*Equivalent percentage of a sample of wheat, etc., when the weights of the sample analyzed and of the mechanical separation are given.*

| Weight of separation. | Weight of sample analyzed (grams). |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
|-----------------------|------------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
|                       | 25                                 | 26   | 27   | 28   | 29   | 30   | 31   | 32   | 33   | 34   | 35   | 36   | 37   | 38   | 39   | 40   | 41   | 42   | 43   | 44   |
| 0.1 gram.....         | 0.4                                | 0.4  | 0.4  | 0.3  | 0.3  | 0.3  | 0.3  | 0.3  | 0.3  | 0.3  | 0.3  | 0.3  | 0.3  | 0.3  | 0.2  | 0.2  | 0.2  | 0.2  | 0.2  | 0.2  |
| .2 gram.....          | .8                                 | .8   | .7   | .7   | .7   | .7   | .6   | .6   | .6   | .6   | .6   | .5   | .5   | .5   | .5   | .5   | .5   | .5   | .5   | .4   |
| .3 gram.....          | 1.2                                | 1.1  | 1.1  | 1.1  | 1.0  | 1.0  | 1.0  | .9   | .9   | .9   | .8   | .8   | .8   | .8   | .7   | .7   | .7   | .7   | .7   | .7   |
| .4 gram.....          | 1.6                                | 1.5  | 1.5  | 1.4  | 1.4  | 1.3  | 1.3  | 1.2  | 1.2  | 1.1  | 1.1  | 1.1  | 1.1  | 1.0  | 1.0  | 1.0  | .9   | .9   | .9   | .9   |
| .5 gram.....          | 2.0                                | 1.9  | 1.8  | 1.8  | 1.7  | 1.7  | 1.6  | 1.6  | 1.5  | 1.5  | 1.4  | 1.4  | 1.3  | 1.3  | 1.3  | 1.2  | 1.2  | 1.2  | 1.2  | 1.1  |
| .6 gram.....          | 2.4                                | 2.3  | 2.2  | 2.1  | 2.1  | 2.0  | 1.9  | 1.9  | 1.8  | 1.8  | 1.7  | 1.7  | 1.6  | 1.6  | 1.5  | 1.5  | 1.5  | 1.4  | 1.4  | 1.4  |
| .7 gram.....          | 2.8                                | 2.7  | 2.6  | 2.5  | 2.4  | 2.3  | 2.2  | 2.2  | 2.1  | 2.0  | 2.0  | 1.9  | 1.9  | 1.8  | 1.8  | 1.7  | 1.7  | 1.7  | 1.6  | 1.6  |
| .8 gram.....          | 3.2                                | 3.1  | 3.0  | 2.8  | 2.7  | 2.7  | 2.6  | 2.5  | 2.4  | 2.3  | 2.3  | 2.2  | 2.2  | 2.1  | 2.0  | 2.0  | 1.9  | 1.9  | 1.9  | 1.8  |
| .9 gram.....          | 3.6                                | 3.5  | 3.3  | 3.2  | 3.1  | 3.0  | 2.9  | 2.8  | 2.7  | 2.6  | 2.6  | 2.5  | 2.4  | 2.4  | 2.3  | 2.2  | 2.2  | 2.1  | 2.1  | 2.0  |
| 1.0 gram.....         | 4.0                                | 3.8  | 3.7  | 3.6  | 3.4  | 3.3  | 3.2  | 3.1  | 3.0  | 2.9  | 2.8  | 2.8  | 2.7  | 2.6  | 2.6  | 2.5  | 2.4  | 2.4  | 2.3  | 2.3  |
| 1.1 grams.....        | 4.4                                | 4.2  | 4.1  | 3.9  | 3.8  | 3.7  | 3.5  | 3.4  | 3.3  | 3.2  | 3.1  | 3.0  | 3.0  | 2.9  | 2.8  | 2.7  | 2.7  | 2.6  | 2.5  | 2.5  |
| 1.2 grams.....        | 4.8                                | 4.6  | 4.4  | 4.3  | 4.1  | 4.0  | 3.9  | 3.7  | 3.6  | 3.5  | 3.4  | 3.3  | 3.2  | 3.1  | 3.1  | 3.0  | 2.9  | 2.8  | 2.8  | 2.7  |
| 1.3 grams.....        | 5.2                                | 5.0  | 4.8  | 4.6  | 4.5  | 4.3  | 4.2  | 4.1  | 3.9  | 3.8  | 3.7  | 3.6  | 3.5  | 3.4  | 3.3  | 3.2  | 3.2  | 3.1  | 3.0  | 2.9  |
| 1.4 grams.....        | 5.6                                | 5.4  | 5.2  | 5.0  | 4.8  | 4.7  | 4.5  | 4.4  | 4.2  | 4.1  | 4.0  | 3.9  | 3.8  | 3.7  | 3.6  | 3.5  | 3.4  | 3.3  | 3.2  | 3.2  |
| 1.5 grams.....        | 6.0                                | 5.8  | 5.5  | 5.3  | 5.2  | 5.0  | 4.8  | 4.7  | 4.5  | 4.4  | 4.3  | 4.2  | 4.0  | 3.9  | 3.8  | 3.7  | 3.6  | 3.6  | 3.5  | 3.4  |
| 1.6 grams.....        | 6.4                                | 6.1  | 5.9  | 5.7  | 5.5  | 5.3  | 5.2  | 5.0  | 4.8  | 4.7  | 4.6  | 4.4  | 4.3  | 4.2  | 4.1  | 4.0  | 3.9  | 3.8  | 3.7  | 3.6  |
| 1.7 grams.....        | 6.8                                | 6.5  | 6.3  | 6.1  | 5.9  | 5.7  | 5.5  | 5.3  | 5.1  | 5.0  | 4.8  | 4.7  | 4.6  | 4.5  | 4.3  | 4.2  | 4.1  | 4.0  | 3.9  | 3.9  |
| 1.8 grams.....        | 7.2                                | 6.9  | 6.7  | 6.4  | 6.2  | 6.0  | 5.8  | 5.6  | 5.4  | 5.3  | 5.1  | 5.0  | 4.9  | 4.7  | 4.6  | 4.5  | 4.4  | 4.3  | 4.2  | 4.1  |
| 1.9 grams.....        | 7.6                                | 7.3  | 7.0  | 6.8  | 6.5  | 6.3  | 6.1  | 5.9  | 5.7  | 5.6  | 5.4  | 5.3  | 5.1  | 5.0  | 4.9  | 4.7  | 4.6  | 4.5  | 4.4  | 4.3  |
| 2.0 grams.....        | 8.0                                | 7.7  | 7.4  | 7.1  | 6.9  | 6.7  | 6.4  | 6.2  | 6.1  | 5.9  | 5.7  | 5.5  | 5.4  | 5.3  | 5.1  | 5.0  | 4.9  | 4.8  | 4.6  | 4.5  |
| 2.1 grams.....        | 8.4                                | 8.1  | 7.8  | 7.5  | 7.2  | 7.0  | 6.8  | 6.6  | 6.4  | 6.2  | 6.0  | 5.8  | 5.7  | 5.5  | 5.4  | 5.2  | 5.1  | 5.0  | 4.9  | 4.8  |
| 2.2 grams.....        | 8.8                                | 8.5  | 8.1  | 7.8  | 7.6  | 7.3  | 7.1  | 6.9  | 6.7  | 6.5  | 6.3  | 6.1  | 5.9  | 5.8  | 5.6  | 5.5  | 5.4  | 5.2  | 5.1  | 5.0  |
| 2.3 grams.....        | 9.2                                | 8.8  | 8.5  | 8.2  | 7.9  | 7.7  | 7.4  | 7.2  | 7.0  | 6.8  | 6.6  | 6.4  | 6.2  | 6.0  | 5.9  | 5.7  | 5.6  | 5.5  | 5.3  | 5.2  |
| 2.4 grams.....        | 9.6                                | 9.2  | 8.9  | 8.6  | 8.3  | 8.0  | 7.7  | 7.5  | 7.3  | 7.0  | 6.8  | 6.7  | 6.5  | 6.3  | 6.1  | 6.0  | 5.8  | 5.7  | 5.6  | 5.4  |
| 2.5 grams.....        | 10.0                               | 9.6  | 9.2  | 8.9  | 8.6  | 8.3  | 8.1  | 7.8  | 7.6  | 7.3  | 7.1  | 6.9  | 6.7  | 6.6  | 6.4  | 6.2  | 6.1  | 5.9  | 5.8  | 5.7  |
| 2.6 grams.....        | 10.4                               | 10.0 | 9.6  | 9.3  | 9.0  | 8.7  | 8.4  | 8.1  | 7.9  | 7.6  | 7.4  | 7.2  | 7.0  | 6.8  | 6.7  | 6.5  | 6.3  | 6.2  | 6.0  | 5.9  |
| 2.7 grams.....        | 10.8                               | 10.4 | 10.0 | 9.6  | 9.3  | 9.0  | 8.7  | 8.4  | 8.2  | 7.9  | 7.7  | 7.5  | 7.3  | 7.1  | 6.9  | 6.7  | 6.6  | 6.4  | 6.3  | 6.1  |
| 2.8 grams.....        | 11.2                               | 10.8 | 10.4 | 10.0 | 9.6  | 9.3  | 9.0  | 8.7  | 8.5  | 8.2  | 8.0  | 7.8  | 7.6  | 7.4  | 7.2  | 7.0  | 6.8  | 6.7  | 6.5  | 6.4  |
| 2.9 grams.....        | 11.6                               | 11.1 | 10.7 | 10.3 | 10.0 | 9.7  | 9.3  | 9.1  | 8.8  | 8.5  | 8.3  | 8.0  | 7.8  | 7.6  | 7.4  | 7.2  | 7.1  | 6.9  | 6.7  | 6.6  |
| 3.0 grams.....        | 12.0                               | 11.5 | 11.1 | 10.7 | 10.3 | 10.0 | 9.7  | 9.4  | 9.1  | 8.8  | 8.6  | 8.3  | 8.1  | 7.9  | 7.7  | 7.5  | 7.3  | 7.1  | 7.0  | 6.8  |
| 3.1 grams.....        | 12.4                               | 11.9 | 11.5 | 11.1 | 10.7 | 10.3 | 10.0 | 9.7  | 9.4  | 9.1  | 8.8  | 8.6  | 8.4  | 8.1  | 7.9  | 7.7  | 7.6  | 7.4  | 7.2  | 7.0  |
| 3.2 grams.....        | 12.8                               | 12.3 | 11.8 | 11.4 | 11.0 | 10.7 | 10.3 | 10.0 | 9.7  | 9.4  | 9.1  | 8.9  | 8.6  | 8.4  | 8.2  | 8.0  | 7.8  | 7.6  | 7.4  | 7.3  |
| 3.3 grams.....        | 13.2                               | 12.7 | 12.2 | 11.8 | 11.4 | 11.0 | 10.6 | 10.3 | 10.0 | 9.7  | 9.4  | 9.2  | 8.9  | 8.7  | 8.5  | 8.2  | 8.0  | 7.8  | 7.7  | 7.5  |
| 3.4 grams.....        | 13.6                               | 13.1 | 12.6 | 12.1 | 11.7 | 11.3 | 11.0 | 10.6 | 10.3 | 10.0 | 9.7  | 9.4  | 9.2  | 8.9  | 8.7  | 8.5  | 8.3  | 8.1  | 7.9  | 7.7  |
| 3.5 grams.....        | 14.0                               | 13.5 | 13.0 | 12.5 | 12.1 | 11.7 | 11.3 | 10.9 | 10.6 | 10.3 | 10.0 | 9.7  | 9.4  | 9.2  | 9.0  | 8.7  | 8.5  | 8.3  | 8.1  | 7.9  |
| 3.6 grams.....        | 14.4                               | 13.8 | 13.3 | 12.8 | 12.4 | 12.0 | 11.6 | 11.2 | 10.9 | 10.6 | 10.3 | 10.0 | 9.7  | 9.5  | 9.2  | 9.0  | 8.8  | 8.6  | 8.4  | 8.2  |
| 3.7 grams.....        | 14.8                               | 14.2 | 13.7 | 13.2 | 12.7 | 12.3 | 11.9 | 11.6 | 11.2 | 10.9 | 10.6 | 10.3 | 10.0 | 9.7  | 9.5  | 9.2  | 9.0  | 8.8  | 8.6  | 8.4  |
| 3.8 grams.....        | 15.2                               | 14.6 | 14.1 | 13.6 | 13.1 | 12.7 | 12.2 | 11.9 | 11.5 | 11.2 | 10.8 | 10.5 | 10.3 | 10.0 | 9.7  | 9.5  | 9.3  | 9.0  | 8.8  | 8.6  |
| 3.9 grams.....        | 15.6                               | 15.0 | 14.4 | 13.9 | 13.4 | 13.0 | 12.6 | 12.2 | 11.8 | 11.5 | 11.1 | 10.8 | 10.5 | 10.3 | 10.0 | 9.7  | 9.5  | 9.3  | 9.1  | 8.9  |
| 4.0 grams.....        | 16.0                               | 15.4 | 14.8 | 14.3 | 13.8 | 13.3 | 12.9 | 12.5 | 12.1 | 11.8 | 11.4 | 11.0 | 10.8 | 10.5 | 10.2 | 10.0 | 9.7  | 9.5  | 9.3  | 9.1  |
| 4.1 grams.....        | 16.4                               | 15.8 | 15.2 | 14.6 | 14.1 | 13.7 | 13.2 | 12.8 | 12.4 | 12.0 | 11.7 | 11.4 | 11.1 | 10.8 | 10.5 | 10.2 | 10.0 | 9.8  | 9.5  | 9.3  |
| 4.2 grams.....        | 16.8                               | 16.1 | 15.5 | 15.0 | 14.5 | 14.0 | 13.5 | 13.1 | 12.7 | 12.3 | 12.0 | 11.7 | 11.3 | 11.0 | 10.8 | 10.5 | 10.2 | 10.0 | 9.8  | 9.5  |
| 4.3 grams.....        | 17.2                               | 16.5 | 15.9 | 15.3 | 14.8 | 14.3 | 13.9 | 13.4 | 13.0 | 12.6 | 12.3 | 11.9 | 11.6 | 11.3 | 11.0 | 10.7 | 10.5 | 10.2 | 10.0 | 9.8  |
| 4.4 grams.....        | 17.6                               | 16.9 | 16.3 | 15.7 | 15.2 | 14.7 | 14.2 | 13.7 | 13.3 | 12.9 | 12.6 | 12.2 | 11.9 | 11.6 | 11.3 | 11.0 | 10.7 | 10.5 | 10.2 | 10.0 |
| 4.5 grams.....        | 18.0                               | 17.3 | 16.7 | 16.1 | 15.5 | 15.0 | 14.5 | 14.1 | 13.6 | 13.2 | 12.8 | 12.5 | 12.2 | 11.8 | 11.5 | 11.2 | 11.0 | 10.7 | 10.5 | 10.2 |
| 4.6 grams.....        | 18.4                               | 17.7 | 17.0 | 16.4 | 15.9 | 15.3 | 14.8 | 14.4 | 13.9 | 13.5 | 13.1 | 12.8 | 12.4 | 12.1 | 11.8 | 11.5 | 11.2 | 10.9 | 10.7 | 10.4 |
| 4.7 grams.....        | 18.8                               | 18.1 | 17.4 | 16.8 | 16.2 | 15.7 | 15.2 | 14.7 | 14.2 | 13.8 | 13.4 | 13.0 | 12.7 | 12.4 | 12.0 | 11.7 | 11.5 | 11.2 | 10.9 | 10.7 |
| 4.8 grams.....        | 19.2                               | 18.5 | 17.8 | 17.1 | 16.5 | 16.0 | 15.5 | 15.0 | 14.5 | 14.1 | 13.7 | 13.3 | 13.0 | 12.6 | 12.3 | 12.0 | 11.7 | 11.4 | 11.2 | 10.9 |
| 4.9 grams.....        | 19.6                               | 18.8 | 18.1 | 17.5 | 16.9 | 16.3 | 15.8 | 15.3 | 14.8 | 14.4 | 14.0 | 13.6 | 13.2 | 12.9 | 12.6 | 12.2 | 11.9 | 11.7 | 11.4 | 11.1 |
| 5.0 grams.....        | 20.0                               | 19.2 | 18.5 | 17.8 | 17.2 | 16.7 | 16.1 | 15.6 | 15.1 | 14.7 | 14.3 | 13.9 | 13.5 | 13.1 | 12.8 | 12.5 | 12.2 | 11.9 | 11.6 | 11.4 |

TABLE I.—*Equivalent percentage of a sample of wheat, etc., when the weights of the sample analyzed and of the mechanical separation are given—Continued.*

| Weight of separation. | Weight of sample analyzed (grams). |      |      |      |      |      |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |  |  |  |  |
|-----------------------|------------------------------------|------|------|------|------|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|--|--|--|--|
|                       | 45                                 | 46   | 47   | 48   | 49   | 50   | 51  | 52  | 53  | 54  | 55  | 56  | 57  | 58  | 59  | 60  | 61  | 62  | 63  | 64  | 65  |     |  |  |  |  |
| 0.1 gram...           | 0.2                                | 0.2  | 0.2  | 0.2  | 0.2  | 0.2  | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 |  |  |  |  |
| .2 gram...            | .4                                 | .4   | .4   | .4   | .4   | .4   | .4  | .4  | .4  | .4  | .4  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  |     |  |  |  |  |
| .3 gram...            | .7                                 | .6   | .6   | .6   | .6   | .6   | .6  | .6  | .6  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  |     |  |  |  |  |
| .4 gram...            | .9                                 | .9   | .8   | .8   | .8   | .8   | .8  | .8  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .6  | .6  | .6  | .6  | .6  |     |  |  |  |  |
| .5 gram...            | 1.1                                | 1.1  | 1.1  | 1.0  | 1.0  | 1.0  | 1.0 | 1.0 | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .8  | .8  | .8  | .8  | .8  | .8  |     |  |  |  |  |
| .6 gram...            | 1.3                                | 1.3  | 1.3  | 1.2  | 1.2  | 1.2  | 1.2 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | .9  | .9  |     |  |  |  |  |
| .7 gram...            | 1.5                                | 1.5  | 1.5  | 1.4  | 1.4  | 1.4  | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 |     |  |  |  |  |
| .8 gram...            | 1.8                                | 1.7  | 1.7  | 1.7  | 1.6  | 1.6  | 1.6 | 1.5 | 1.5 | 1.5 | 1.4 | 1.4 | 1.4 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.2 | 1.2 |     |  |  |  |  |
| .9 gram...            | 2.0                                | 1.9  | 1.9  | 1.9  | 1.8  | 1.8  | 1.8 | 1.7 | 1.7 | 1.7 | 1.6 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 | 1.4 | 1.4 | 1.4 |     |  |  |  |  |
| 1.0 gram...           | 2.2                                | 2.2  | 2.1  | 2.1  | 2.0  | 2.0  | 2.0 | 1.9 | 1.9 | 1.8 | 1.8 | 1.8 | 1.7 | 1.7 | 1.7 | 1.7 | 1.6 | 1.6 | 1.6 | 1.6 | 1.5 |     |  |  |  |  |
| 1.1 grams...          | 2.4                                | 2.4  | 2.3  | 2.3  | 2.2  | 2.2  | 2.1 | 2.1 | 2.1 | 2.0 | 2.0 | 2.0 | 1.9 | 1.9 | 1.9 | 1.8 | 1.8 | 1.8 | 1.7 | 1.7 | 1.7 |     |  |  |  |  |
| 1.2 grams...          | 2.7                                | 2.6  | 2.5  | 2.5  | 2.4  | 2.4  | 2.3 | 2.3 | 2.3 | 2.2 | 2.2 | 2.1 | 2.1 | 2.1 | 2.0 | 2.0 | 2.0 | 1.9 | 1.9 | 1.9 | 1.8 |     |  |  |  |  |
| 1.3 grams...          | 2.9                                | 2.8  | 2.8  | 2.7  | 2.6  | 2.6  | 2.5 | 2.5 | 2.4 | 2.4 | 2.4 | 2.3 | 2.3 | 2.2 | 2.2 | 2.2 | 2.1 | 2.1 | 2.1 | 2.0 | 2.0 |     |  |  |  |  |
| 1.4 grams...          | 3.1                                | 3.0  | 3.0  | 2.9  | 2.8  | 2.8  | 2.7 | 2.7 | 2.6 | 2.6 | 2.5 | 2.5 | 2.4 | 2.4 | 2.4 | 2.3 | 2.3 | 2.2 | 2.2 | 2.2 | 2.1 |     |  |  |  |  |
| 1.5 grams...          | 3.3                                | 3.3  | 3.2  | 3.1  | 3.1  | 3.0  | 2.9 | 2.9 | 2.8 | 2.8 | 2.7 | 2.7 | 2.6 | 2.6 | 2.5 | 2.5 | 2.4 | 2.4 | 2.4 | 2.3 | 2.3 |     |  |  |  |  |
| 1.6 grams...          | 3.5                                | 3.5  | 3.4  | 3.3  | 3.3  | 3.2  | 3.1 | 3.1 | 3.0 | 3.0 | 2.9 | 2.8 | 2.8 | 2.7 | 2.7 | 2.7 | 2.6 | 2.6 | 2.5 | 2.5 | 2.5 |     |  |  |  |  |
| 1.7 grams...          | 3.8                                | 3.7  | 3.6  | 3.5  | 3.5  | 3.4  | 3.3 | 3.3 | 3.2 | 3.1 | 3.1 | 3.0 | 3.0 | 2.9 | 2.9 | 2.8 | 2.8 | 2.7 | 2.7 | 2.6 | 2.6 |     |  |  |  |  |
| 1.8 grams...          | 4.0                                | 3.9  | 3.8  | 3.7  | 3.7  | 3.6  | 3.5 | 3.5 | 3.4 | 3.3 | 3.3 | 3.2 | 3.1 | 3.1 | 3.0 | 3.0 | 2.9 | 2.9 | 2.8 | 2.8 | 2.8 |     |  |  |  |  |
| 1.9 grams...          | 4.2                                | 4.1  | 4.0  | 3.9  | 3.9  | 3.8  | 3.7 | 3.6 | 3.6 | 3.5 | 3.4 | 3.4 | 3.3 | 3.3 | 3.2 | 3.2 | 3.1 | 3.1 | 3.0 | 3.0 | 2.9 |     |  |  |  |  |
| 2.0 grams...          | 4.4                                | 4.3  | 4.2  | 4.2  | 4.1  | 4.0  | 3.9 | 3.8 | 3.8 | 3.7 | 3.6 | 3.6 | 3.5 | 3.4 | 3.4 | 3.3 | 3.3 | 3.2 | 3.2 | 3.1 | 3.1 |     |  |  |  |  |
| 2.1 grams...          | 4.7                                | 4.6  | 4.5  | 4.4  | 4.3  | 4.2  | 4.1 | 4.0 | 4.0 | 3.9 | 3.8 | 3.7 | 3.7 | 3.6 | 3.5 | 3.5 | 3.4 | 3.4 | 3.3 | 3.3 | 3.2 |     |  |  |  |  |
| 2.2 grams...          | 4.9                                | 4.8  | 4.7  | 4.6  | 4.5  | 4.4  | 4.3 | 4.2 | 4.1 | 4.1 | 4.0 | 3.9 | 3.8 | 3.8 | 3.7 | 3.7 | 3.6 | 3.5 | 3.5 | 3.4 | 3.4 |     |  |  |  |  |
| 2.3 grams...          | 5.1                                | 5.0  | 4.9  | 4.8  | 4.7  | 4.6  | 4.5 | 4.4 | 4.3 | 4.2 | 4.2 | 4.1 | 4.0 | 4.0 | 3.9 | 3.8 | 3.8 | 3.7 | 3.6 | 3.6 | 3.5 |     |  |  |  |  |
| 2.4 grams...          | 5.3                                | 5.2  | 5.1  | 5.0  | 4.9  | 4.8  | 4.7 | 4.6 | 4.5 | 4.4 | 4.3 | 4.2 | 4.1 | 4.1 | 4.0 | 3.9 | 3.9 | 3.8 | 3.7 | 3.7 | 3.6 |     |  |  |  |  |
| 2.5 grams...          | 5.5                                | 5.4  | 5.3  | 5.2  | 5.1  | 5.0  | 4.9 | 4.8 | 4.7 | 4.6 | 4.5 | 4.5 | 4.4 | 4.3 | 4.2 | 4.2 | 4.1 | 4.0 | 4.0 | 3.9 | 3.8 |     |  |  |  |  |
| 2.6 grams...          | 5.8                                | 5.6  | 5.5  | 5.4  | 5.3  | 5.2  | 5.1 | 5.0 | 4.9 | 4.8 | 4.7 | 4.6 | 4.5 | 4.4 | 4.3 | 4.3 | 4.2 | 4.1 | 4.1 | 4.0 | 4.0 |     |  |  |  |  |
| 2.7 grams...          | 6.0                                | 5.9  | 5.7  | 5.6  | 5.5  | 5.4  | 5.3 | 5.2 | 5.1 | 5.0 | 4.9 | 4.8 | 4.7 | 4.6 | 4.5 | 4.5 | 4.4 | 4.3 | 4.3 | 4.2 | 4.1 |     |  |  |  |  |
| 2.8 grams...          | 6.2                                | 6.1  | 5.9  | 5.8  | 5.7  | 5.6  | 5.5 | 5.4 | 5.3 | 5.2 | 5.1 | 5.0 | 4.9 | 4.8 | 4.7 | 4.7 | 4.6 | 4.5 | 4.4 | 4.4 | 4.3 |     |  |  |  |  |
| 2.9 grams...          | 6.4                                | 6.3  | 6.2  | 6.0  | 5.9  | 5.8  | 5.7 | 5.6 | 5.5 | 5.4 | 5.3 | 5.2 | 5.1 | 5.0 | 4.9 | 4.8 | 4.7 | 4.7 | 4.6 | 4.5 | 4.5 |     |  |  |  |  |
| 3.0 grams...          | 6.7                                | 6.5  | 6.4  | 6.2  | 6.1  | 6.0  | 5.9 | 5.8 | 5.7 | 5.6 | 5.5 | 5.4 | 5.3 | 5.2 | 5.1 | 5.0 | 4.9 | 4.8 | 4.8 | 4.7 | 4.6 |     |  |  |  |  |
| 3.1 grams...          | 6.9                                | 6.7  | 6.6  | 6.4  | 6.3  | 6.2  | 6.1 | 6.0 | 5.8 | 5.7 | 5.6 | 5.5 | 5.4 | 5.3 | 5.2 | 5.1 | 5.0 | 4.9 | 4.8 | 4.8 | 4.7 |     |  |  |  |  |
| 3.2 grams...          | 7.1                                | 6.9  | 6.8  | 6.7  | 6.5  | 6.4  | 6.3 | 6.1 | 6.0 | 5.9 | 5.8 | 5.7 | 5.6 | 5.5 | 5.4 | 5.3 | 5.2 | 5.2 | 5.1 | 5.0 | 4.9 |     |  |  |  |  |
| 3.3 grams...          | 7.3                                | 7.2  | 7.0  | 6.9  | 6.7  | 6.6  | 6.5 | 6.3 | 6.2 | 6.1 | 6.0 | 5.9 | 5.8 | 5.7 | 5.6 | 5.5 | 5.4 | 5.3 | 5.2 | 5.1 | 5.1 |     |  |  |  |  |
| 3.4 grams...          | 7.5                                | 7.4  | 7.2  | 7.1  | 6.9  | 6.8  | 6.7 | 6.5 | 6.4 | 6.3 | 6.2 | 6.1 | 6.0 | 5.9 | 5.8 | 5.7 | 5.6 | 5.5 | 5.4 | 5.3 | 5.2 |     |  |  |  |  |
| 3.5 grams...          | 7.8                                | 7.6  | 7.4  | 7.3  | 7.1  | 7.0  | 6.9 | 6.7 | 6.6 | 6.5 | 6.4 | 6.2 | 6.1 | 6.0 | 5.9 | 5.8 | 5.7 | 5.6 | 5.5 | 5.5 | 5.4 |     |  |  |  |  |
| 3.6 grams...          | 8.0                                | 7.8  | 7.6  | 7.5  | 7.3  | 7.2  | 7.0 | 6.9 | 6.8 | 6.7 | 6.5 | 6.4 | 6.3 | 6.2 | 6.1 | 6.0 | 5.9 | 5.8 | 5.7 | 5.6 | 5.5 |     |  |  |  |  |
| 3.7 grams...          | 8.2                                | 8.0  | 7.9  | 7.7  | 7.5  | 7.4  | 7.2 | 7.1 | 7.0 | 6.8 | 6.7 | 6.6 | 6.5 | 6.4 | 6.3 | 6.2 | 6.1 | 6.0 | 5.9 | 5.8 | 5.7 |     |  |  |  |  |
| 3.8 grams...          | 8.4                                | 8.3  | 8.1  | 7.9  | 7.7  | 7.6  | 7.4 | 7.3 | 7.2 | 7.0 | 6.9 | 6.8 | 6.7 | 6.5 | 6.4 | 6.3 | 6.2 | 6.1 | 6.0 | 5.9 | 5.8 |     |  |  |  |  |
| 3.9 grams...          | 8.7                                | 8.5  | 8.3  | 8.1  | 7.9  | 7.8  | 7.6 | 7.5 | 7.3 | 7.2 | 7.1 | 7.0 | 6.8 | 6.7 | 6.6 | 6.5 | 6.4 | 6.3 | 6.2 | 6.1 | 6.0 |     |  |  |  |  |
| 4.0 grams...          | 8.9                                | 8.7  | 8.5  | 8.3  | 8.2  | 8.0  | 7.8 | 7.7 | 7.5 | 7.4 | 7.3 | 7.1 | 7.0 | 6.9 | 6.8 | 6.7 | 6.5 | 6.4 | 6.3 | 6.2 | 6.1 |     |  |  |  |  |
| 4.1 grams...          | 9.1                                | 8.9  | 8.7  | 8.5  | 8.4  | 8.2  | 8.0 | 7.9 | 7.7 | 7.6 | 7.4 | 7.3 | 7.2 | 7.1 | 6.9 | 6.8 | 6.7 | 6.6 | 6.5 | 6.4 | 6.3 |     |  |  |  |  |
| 4.2 grams...          | 9.3                                | 9.1  | 8.9  | 8.7  | 8.6  | 8.4  | 8.2 | 8.1 | 7.9 | 7.8 | 7.6 | 7.5 | 7.4 | 7.2 | 7.1 | 7.0 | 6.9 | 6.8 | 6.7 | 6.6 | 6.5 |     |  |  |  |  |
| 4.3 grams...          | 9.5                                | 9.3  | 9.1  | 8.9  | 8.8  | 8.6  | 8.4 | 8.3 | 8.1 | 8.0 | 7.8 | 7.7 | 7.5 | 7.4 | 7.3 | 7.2 | 7.0 | 6.9 | 6.8 | 6.7 | 6.6 |     |  |  |  |  |
| 4.4 grams...          | 9.8                                | 9.6  | 9.4  | 9.2  | 9.0  | 8.8  | 8.6 | 8.5 | 8.3 | 8.1 | 8.0 | 7.8 | 7.7 | 7.6 | 7.4 | 7.3 | 7.2 | 7.1 | 7.0 | 6.9 | 6.8 |     |  |  |  |  |
| 4.5 grams...          | 10.0                               | 9.8  | 9.6  | 9.4  | 9.2  | 9.0  | 8.8 | 8.6 | 8.5 | 8.3 | 8.2 | 8.0 | 7.9 | 7.7 | 7.6 | 7.5 | 7.4 | 7.2 | 7.1 | 7.0 | 6.9 |     |  |  |  |  |
| 4.6 grams...          | 10.2                               | 10.0 | 9.8  | 9.6  | 9.4  | 9.2  | 9.0 | 8.8 | 8.7 | 8.5 | 8.4 | 8.2 | 8.1 | 7.9 | 7.8 | 7.7 | 7.5 | 7.4 | 7.3 | 7.2 | 7.1 |     |  |  |  |  |
| 4.7 grams...          | 10.4                               | 10.2 | 10.0 | 9.8  | 9.6  | 9.4  | 9.2 | 9.0 | 8.9 | 8.7 | 8.5 | 8.4 | 8.2 | 8.1 | 8.0 | 7.8 | 7.7 | 7.6 | 7.5 | 7.3 | 7.2 |     |  |  |  |  |
| 4.8 grams...          | 10.7                               | 10.4 | 10.2 | 10.0 | 9.8  | 9.6  | 9.4 | 9.2 | 9.0 | 8.9 | 8.7 | 8.6 | 8.4 | 8.3 | 8.1 | 8.0 | 7.9 | 7.7 | 7.6 | 7.5 | 7.4 |     |  |  |  |  |
| 4.9 grams...          | 10.9                               | 10.6 | 10.4 | 10.2 | 10.0 | 9.8  | 9.6 | 9.4 | 9.2 | 9.1 | 8.9 | 8.7 | 8.6 | 8.4 | 8.3 | 8.2 | 8.0 | 7.9 | 7.8 | 7.6 | 7.5 |     |  |  |  |  |
| 5.0 grams...          | 11.1                               | 10.9 | 10.6 | 10.4 | 10.2 | 10.0 | 9.8 | 9.6 | 9.4 | 9.2 | 9.1 | 8.9 | 8.8 | 8.6 | 8.5 | 8.3 | 8.2 | 8.1 | 7.9 | 7.8 | 7.7 |     |  |  |  |  |



TABLE I.—*Equivalent percentage of a sample of wheat, etc., when the weights of the sample analyzed and of the mechanical separation are given—Continued.*

| Weight of separation. | Weight of sample analyzed (grams). |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
|-----------------------|------------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
|                       | 25                                 | 26   | 27   | 28   | 29   | 30   | 31   | 32   | 33   | 34   | 35   | 36   | 37   | 38   | 39   | 40   | 41   | 42   | 43   | 44   |
| 5.1 grams....         | 20.4                               | 19.6 | 18.9 | 18.2 | 17.6 | 17.0 | 16.4 | 15.9 | 15.4 | 15.0 | 14.6 | 14.2 | 13.8 | 13.4 | 13.1 | 12.7 | 12.4 | 12.1 | 11.9 | 11.6 |
| 5.2 grams....         | 20.8                               | 20.0 | 19.2 | 18.6 | 17.9 | 17.3 | 16.8 | 16.2 | 15.7 | 15.3 | 14.8 | 14.4 | 14.0 | 13.7 | 13.3 | 13.0 | 12.7 | 12.4 | 12.1 | 11.8 |
| 5.3 grams....         | 21.2                               | 20.4 | 19.6 | 18.9 | 18.3 | 17.7 | 17.1 | 16.6 | 16.1 | 15.6 | 15.1 | 14.7 | 14.3 | 13.9 | 13.6 | 13.2 | 12.9 | 12.6 | 12.3 | 12.0 |
| 5.4 grams....         | 21.6                               | 20.8 | 20.0 | 19.3 | 18.6 | 18.0 | 17.4 | 16.9 | 16.4 | 15.9 | 15.4 | 15.0 | 14.6 | 14.2 | 13.8 | 13.5 | 13.2 | 12.8 | 12.5 | 12.3 |
| 5.5 grams....         | 22.0                               | 21.1 | 20.4 | 19.6 | 19.0 | 18.3 | 17.7 | 17.2 | 16.7 | 16.2 | 15.7 | 15.3 | 14.9 | 14.5 | 14.1 | 13.7 | 13.4 | 13.1 | 12.8 | 12.5 |
| 5.6 grams....         | 22.4                               | 21.5 | 20.7 | 20.0 | 19.3 | 18.7 | 18.1 | 17.5 | 17.0 | 16.5 | 16.0 | 15.5 | 15.1 | 14.7 | 14.3 | 14.0 | 13.6 | 13.3 | 13.0 | 12.7 |
| 5.7 grams....         | 22.8                               | 21.9 | 21.1 | 20.3 | 19.6 | 19.0 | 18.4 | 17.8 | 17.3 | 16.8 | 16.3 | 15.8 | 15.4 | 15.0 | 14.6 | 14.2 | 13.9 | 13.6 | 13.2 | 12.9 |
| 5.8 grams....         | 23.2                               | 22.3 | 21.5 | 20.7 | 20.0 | 19.3 | 18.7 | 18.1 | 17.6 | 17.0 | 16.6 | 16.1 | 15.7 | 15.3 | 14.9 | 14.5 | 14.1 | 13.8 | 13.5 | 13.2 |
| 5.9 grams....         | 23.6                               | 22.7 | 21.8 | 21.1 | 20.3 | 19.7 | 19.0 | 18.4 | 17.9 | 17.3 | 16.8 | 16.4 | 15.9 | 15.5 | 15.1 | 14.7 | 14.4 | 14.0 | 13.7 | 13.4 |
| 6.0 grams....         | 24.0                               | 23.1 | 22.2 | 21.4 | 20.7 | 20.0 | 19.3 | 18.7 | 18.2 | 17.6 | 17.1 | 16.7 | 16.2 | 15.8 | 15.4 | 15.0 | 14.6 | 14.3 | 13.9 | 13.6 |
| 6.1 grams....         | 24.4                               | 23.5 | 22.6 | 21.8 | 21.1 | 20.3 | 19.7 | 19.1 | 18.5 | 17.9 | 17.4 | 16.9 | 16.5 | 16.0 | 15.6 | 15.2 | 14.9 | 14.5 | 14.2 | 13.9 |
| 6.2 grams....         | 24.8                               | 23.8 | 23.0 | 22.2 | 21.4 | 20.7 | 20.0 | 19.4 | 18.8 | 18.2 | 17.7 | 17.2 | 16.7 | 16.3 | 15.9 | 15.5 | 15.1 | 14.8 | 14.4 | 14.1 |
| 6.3 grams....         | 25.2                               | 24.2 | 23.3 | 22.5 | 21.7 | 21.0 | 20.3 | 19.7 | 19.1 | 18.5 | 18.0 | 17.5 | 17.0 | 16.6 | 16.2 | 15.8 | 15.4 | 15.0 | 14.6 | 14.3 |
| 6.4 grams....         | 25.6                               | 24.6 | 23.7 | 22.8 | 22.1 | 21.3 | 20.6 | 20.0 | 19.4 | 18.8 | 18.3 | 17.8 | 17.3 | 16.8 | 16.4 | 16.0 | 15.6 | 15.2 | 14.9 | 14.5 |
| 6.5 grams....         | 26.0                               | 25.0 | 24.1 | 23.2 | 22.4 | 21.7 | 21.0 | 20.3 | 19.7 | 19.1 | 18.6 | 18.0 | 17.6 | 17.1 | 16.7 | 16.2 | 15.8 | 15.5 | 15.1 | 14.8 |
| 6.6 grams....         | 26.4                               | 25.4 | 24.4 | 23.5 | 22.6 | 21.9 | 21.2 | 20.5 | 19.9 | 19.3 | 18.8 | 18.3 | 17.8 | 17.4 | 16.9 | 16.5 | 16.1 | 15.7 | 15.3 | 15.0 |
| 6.7 grams....         | 26.8                               | 25.8 | 24.8 | 23.9 | 23.1 | 22.3 | 21.6 | 20.9 | 20.3 | 19.7 | 19.1 | 18.6 | 18.1 | 17.6 | 17.2 | 16.7 | 16.3 | 15.9 | 15.6 | 15.2 |
| 6.8 grams....         | 27.2                               | 26.1 | 25.2 | 24.3 | 23.4 | 22.7 | 21.9 | 21.2 | 20.6 | 20.0 | 19.4 | 18.9 | 18.4 | 17.9 | 17.4 | 17.0 | 16.6 | 16.2 | 15.8 | 15.4 |
| 6.9 grams....         | 27.6                               | 26.5 | 25.5 | 24.6 | 23.7 | 23.0 | 22.2 | 21.6 | 20.9 | 20.3 | 19.7 | 19.2 | 18.6 | 18.1 | 17.7 | 17.2 | 16.8 | 16.4 | 16.0 | 15.7 |
| 7.0 grams....         | 28.0                               | 26.9 | 25.9 | 25.0 | 24.1 | 23.3 | 22.6 | 21.9 | 21.2 | 20.6 | 20.0 | 19.4 | 18.9 | 18.4 | 17.9 | 17.5 | 17.0 | 16.6 | 16.2 | 15.9 |
| 7.1 grams....         | 28.4                               | 27.3 | 26.3 | 25.3 | 24.5 | 23.7 | 22.9 | 22.2 | 21.5 | 20.9 | 20.3 | 19.7 | 19.2 | 18.7 | 18.2 | 17.7 | 17.3 | 16.9 | 16.5 | 16.1 |
| 7.2 grams....         | 28.8                               | 27.7 | 26.7 | 25.7 | 24.8 | 24.0 | 23.2 | 22.5 | 21.8 | 21.2 | 20.6 | 20.0 | 19.4 | 18.9 | 18.5 | 18.0 | 17.6 | 17.1 | 16.7 | 16.4 |
| 7.3 grams....         | 29.2                               | 28.1 | 27.0 | 26.1 | 25.2 | 24.3 | 23.5 | 22.8 | 22.1 | 21.5 | 20.8 | 20.3 | 19.7 | 19.2 | 18.7 | 18.2 | 17.8 | 17.4 | 17.0 | 16.6 |
| 7.4 grams....         | 29.6                               | 28.5 | 27.4 | 26.4 | 25.5 | 24.6 | 23.8 | 23.1 | 22.4 | 21.8 | 21.2 | 20.6 | 20.0 | 19.5 | 19.0 | 18.5 | 18.0 | 17.6 | 17.2 | 16.8 |
| 7.5 grams....         | 30.0                               | 28.8 | 27.8 | 26.8 | 25.9 | 25.0 | 24.2 | 23.4 | 22.7 | 22.0 | 21.4 | 20.8 | 20.3 | 19.7 | 19.2 | 18.7 | 18.3 | 17.8 | 17.4 | 17.0 |
| 7.6 grams....         | 30.4                               | 29.2 | 28.1 | 27.1 | 26.2 | 25.3 | 24.5 | 23.7 | 23.0 | 22.3 | 21.7 | 21.1 | 20.5 | 20.0 | 19.5 | 19.0 | 18.5 | 18.1 | 17.7 | 17.3 |
| 7.7 grams....         | 30.8                               | 29.6 | 28.5 | 27.5 | 26.5 | 25.7 | 24.8 | 24.1 | 23.3 | 22.6 | 22.0 | 21.4 | 20.8 | 20.3 | 19.7 | 19.2 | 18.8 | 18.3 | 17.9 | 17.5 |
| 7.8 grams....         | 31.2                               | 30.0 | 28.9 | 27.9 | 26.9 | 26.0 | 25.2 | 24.4 | 23.6 | 22.9 | 22.3 | 21.7 | 21.1 | 20.5 | 20.0 | 19.5 | 19.0 | 18.6 | 18.1 | 17.7 |
| 7.9 grams....         | 31.6                               | 30.4 | 29.2 | 28.2 | 27.2 | 26.3 | 25.5 | 24.7 | 23.9 | 23.2 | 22.6 | 21.9 | 21.3 | 20.8 | 20.2 | 19.7 | 19.3 | 18.8 | 18.4 | 17.9 |
| 8.0 grams....         | 32.0                               | 30.8 | 29.6 | 28.6 | 27.6 | 26.7 | 25.8 | 25.0 | 24.2 | 23.5 | 22.8 | 22.2 | 21.6 | 21.0 | 20.5 | 20.0 | 19.5 | 19.0 | 18.6 | 18.2 |
| 8.1 grams....         | 32.4                               | 31.1 | 30.0 | 28.9 | 27.9 | 27.0 | 26.1 | 25.3 | 24.5 | 23.8 | 23.1 | 22.5 | 21.9 | 21.3 | 20.8 | 20.2 | 19.7 | 19.3 | 18.8 | 18.4 |
| 8.2 grams....         | 32.8                               | 31.5 | 30.4 | 29.3 | 28.3 | 27.3 | 26.4 | 25.6 | 24.8 | 24.1 | 23.4 | 22.8 | 22.2 | 21.6 | 21.0 | 20.5 | 20.0 | 19.5 | 19.1 | 18.6 |
| 8.3 grams....         | 33.2                               | 31.9 | 30.7 | 29.6 | 28.6 | 27.7 | 26.8 | 25.9 | 25.1 | 24.4 | 23.7 | 23.0 | 22.4 | 21.8 | 21.2 | 20.7 | 20.2 | 19.8 | 19.3 | 18.9 |
| 8.4 grams....         | 33.6                               | 32.3 | 31.1 | 30.0 | 29.0 | 28.0 | 27.1 | 26.2 | 25.4 | 24.7 | 24.0 | 23.3 | 22.7 | 22.1 | 21.5 | 21.0 | 20.5 | 20.0 | 19.5 | 19.1 |
| 8.5 grams....         | 34.0                               | 32.7 | 31.5 | 30.3 | 29.3 | 28.3 | 27.4 | 26.6 | 25.7 | 25.0 | 24.3 | 23.6 | 23.0 | 22.4 | 21.8 | 21.2 | 20.7 | 20.2 | 19.8 | 19.3 |
| 8.6 grams....         | 34.4                               | 33.1 | 31.8 | 30.7 | 29.6 | 28.7 | 27.7 | 26.9 | 26.1 | 25.3 | 24.6 | 23.9 | 23.2 | 22.6 | 22.0 | 21.5 | 21.0 | 20.5 | 20.0 | 19.5 |
| 8.7 grams....         | 34.8                               | 33.5 | 32.2 | 31.1 | 30.0 | 29.0 | 28.1 | 27.2 | 26.4 | 25.6 | 24.8 | 24.1 | 23.5 | 22.9 | 22.3 | 21.7 | 21.2 | 20.7 | 20.2 | 19.8 |
| 8.8 grams....         | 35.2                               | 33.8 | 32.6 | 31.4 | 30.3 | 29.3 | 28.4 | 27.5 | 26.7 | 25.9 | 25.1 | 24.4 | 23.8 | 23.2 | 22.6 | 22.0 | 21.5 | 20.9 | 20.5 | 20.0 |
| 8.9 grams....         | 35.6                               | 34.2 | 33.0 | 31.8 | 30.7 | 29.7 | 28.7 | 27.8 | 27.0 | 26.2 | 25.4 | 24.7 | 24.0 | 23.4 | 22.8 | 22.2 | 21.7 | 21.2 | 20.7 | 20.2 |
| 9.0 grams....         | 36.0                               | 34.6 | 33.3 | 32.1 | 31.0 | 30.0 | 29.0 | 28.1 | 27.3 | 26.5 | 25.7 | 25.0 | 24.3 | 23.7 | 23.1 | 22.5 | 21.9 | 21.4 | 20.9 | 20.4 |
| 9.1 grams....         | 36.4                               | 35.0 | 33.7 | 32.5 | 31.4 | 30.3 | 29.3 | 28.4 | 27.6 | 26.8 | 26.0 | 25.3 | 24.6 | 23.9 | 23.3 | 22.7 | 22.2 | 21.7 | 21.2 | 20.7 |
| 9.2 grams....         | 36.8                               | 35.4 | 34.1 | 32.8 | 31.7 | 30.7 | 29.7 | 28.7 | 27.9 | 27.1 | 26.3 | 25.5 | 24.9 | 24.2 | 23.6 | 23.0 | 22.4 | 21.9 | 21.4 | 20.9 |
| 9.3 grams....         | 37.2                               | 35.8 | 34.4 | 33.2 | 32.1 | 31.0 | 30.0 | 29.1 | 28.2 | 27.4 | 26.6 | 25.8 | 25.1 | 24.5 | 23.8 | 23.2 | 22.7 | 22.2 | 21.7 | 21.2 |
| 9.4 grams....         | 37.6                               | 36.1 | 34.8 | 33.5 | 32.4 | 31.3 | 30.3 | 29.4 | 28.5 | 27.6 | 26.8 | 26.0 | 25.3 | 24.7 | 24.0 | 23.4 | 22.8 | 22.3 | 21.8 | 21.3 |
| 9.5 grams....         | 38.0                               | 36.5 | 35.2 | 33.9 | 32.8 | 31.7 | 30.7 | 29.7 | 28.8 | 27.9 | 27.1 | 26.3 | 25.5 | 24.9 | 24.2 | 23.6 | 23.0 | 22.5 | 22.0 | 21.5 |
| 9.6 grams....         | 38.4                               | 36.9 | 35.5 | 34.3 | 33.2 | 32.1 | 31.0 | 30.0 | 29.1 | 28.2 | 27.4 | 26.6 | 25.8 | 25.1 | 24.5 | 23.8 | 23.2 | 22.7 | 22.2 | 21.7 |
| 9.7 grams....         | 38.8                               | 37.3 | 35.9 | 34.6 | 33.5 | 32.4 | 31.3 | 30.3 | 29.4 | 28.5 | 27.7 | 26.9 | 26.1 | 25.4 | 24.8 | 24.1 | 23.5 | 23.0 | 22.5 | 22.0 |
| 9.8 grams....         | 39.2                               | 37.7 | 36.3 | 35.0 | 33.8 | 32.7 | 31.6 | 30.6 | 29.7 | 28.8 | 28.0 | 27.2 | 26.4 | 25.7 | 25.0 | 24.4 | 23.8 | 23.3 | 22.8 | 22.3 |
| 9.9 grams....         | 39.6                               | 38.1 | 36.7 | 35.4 | 34.3 | 33.2 | 32.1 | 31.0 | 30.0 | 29.1 | 28.3 | 27.5 | 26.7 | 26.0 | 25.4 | 24.7 | 24.1 | 23.6 | 23.1 | 22.6 |
| 10.0 grams....        | 40.0                               | 38.5 | 37.0 | 35.7 | 34.5 | 33.3 | 32.2 | 31.2 | 30.3 | 29.4 | 28.6 | 27.8 | 27.0 | 26.3 | 25.6 | 25.0 | 24.4 | 23.8 | 23.3 | 22.7 |

TABLE I.—Equivalent percentage of a sample of wheat, etc., when the weights of the sample analyzed and of the mechanical separation are given—Continued.

| Weight of separation. | Weight of sample analyzed (grams). |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
|-----------------------|------------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
|                       | 45                                 | 46   | 47   | 48   | 49   | 50   | 51   | 52   | 53   | 54   | 55   | 56   | 57   | 58   | 59   | 60   | 61   | 62   | 63   | 64   |
| 5.1 grams             | 11.3                               | 11.1 | 10.8 | 10.6 | 10.4 | 10.2 | 10.0 | 9.8  | 9.6  | 9.4  | 9.2  | 9.1  | 8.9  | 8.8  | 8.6  | 8.5  | 8.4  | 8.2  | 8.1  | 8.0  |
| 5.2 grams             | 11.5                               | 11.3 | 11.1 | 10.8 | 10.6 | 10.4 | 10.2 | 10.0 | 9.8  | 9.6  | 9.4  | 9.3  | 9.1  | 9.0  | 8.8  | 8.7  | 8.5  | 8.4  | 8.2  | 8.1  |
| 5.3 grams             | 11.8                               | 11.5 | 11.3 | 11.0 | 10.8 | 10.6 | 10.4 | 10.2 | 10.0 | 9.8  | 9.6  | 9.5  | 9.3  | 9.1  | 9.0  | 8.8  | 8.7  | 8.5  | 8.4  | 8.3  |
| 5.4 grams             | 12.0                               | 11.7 | 11.5 | 11.2 | 11.0 | 10.8 | 10.6 | 10.4 | 10.2 | 10.0 | 9.8  | 9.6  | 9.5  | 9.3  | 9.1  | 9.0  | 8.8  | 8.7  | 8.6  | 8.4  |
| 5.5 grams             | 12.2                               | 11.9 | 11.7 | 11.4 | 11.2 | 11.0 | 10.8 | 10.6 | 10.4 | 10.2 | 10.0 | 9.8  | 9.6  | 9.5  | 9.3  | 9.2  | 9.0  | 8.9  | 8.7  | 8.6  |
| 5.6 grams             | 12.4                               | 12.2 | 11.9 | 11.7 | 11.4 | 11.2 | 11.0 | 10.8 | 10.6 | 10.4 | 10.2 | 10.0 | 9.8  | 9.6  | 9.5  | 9.3  | 9.2  | 9.0  | 8.9  | 8.7  |
| 5.7 grams             | 12.7                               | 12.4 | 12.1 | 11.9 | 11.6 | 11.4 | 11.2 | 11.0 | 10.7 | 10.5 | 10.4 | 10.2 | 10.0 | 9.8  | 9.7  | 9.5  | 9.3  | 9.2  | 9.0  | 8.9  |
| 5.8 grams             | 12.9                               | 12.6 | 12.3 | 12.1 | 11.8 | 11.6 | 11.4 | 11.1 | 10.9 | 10.7 | 10.5 | 10.3 | 10.2 | 10.0 | 9.8  | 9.7  | 9.5  | 9.3  | 9.2  | 9.1  |
| 5.9 grams             | 13.1                               | 12.8 | 12.5 | 12.3 | 12.0 | 11.8 | 11.6 | 11.3 | 11.1 | 10.9 | 10.7 | 10.5 | 10.3 | 10.2 | 10.0 | 9.8  | 9.7  | 9.5  | 9.4  | 9.2  |
| 6.0 grams             | 13.3                               | 13.0 | 12.8 | 12.5 | 12.2 | 12.0 | 11.8 | 11.5 | 11.3 | 11.0 | 10.9 | 10.7 | 10.5 | 10.3 | 10.2 | 10.0 | 9.8  | 9.7  | 9.5  | 9.4  |
| 6.1 grams             | 13.5                               | 13.3 | 13.0 | 12.7 | 12.4 | 12.2 | 12.0 | 11.7 | 11.5 | 11.3 | 11.1 | 10.9 | 10.7 | 10.5 | 10.3 | 10.2 | 10.0 | 9.8  | 9.7  | 9.5  |
| 6.2 grams             | 13.8                               | 13.5 | 13.2 | 12.9 | 12.6 | 12.4 | 12.1 | 11.9 | 11.7 | 11.5 | 11.3 | 11.1 | 10.9 | 10.7 | 10.5 | 10.3 | 10.2 | 10.0 | 9.8  | 9.7  |
| 6.3 grams             | 14.0                               | 13.7 | 13.4 | 13.1 | 12.8 | 12.6 | 12.3 | 12.1 | 11.9 | 11.7 | 11.4 | 11.2 | 11.0 | 10.9 | 10.7 | 10.5 | 10.3 | 10.2 | 10.0 | 9.8  |
| 6.4 grams             | 14.2                               | 13.9 | 13.6 | 13.3 | 13.0 | 12.8 | 12.5 | 12.3 | 12.1 | 11.8 | 11.6 | 11.4 | 11.2 | 11.0 | 10.8 | 10.6 | 10.5 | 10.3 | 10.1 | 9.8  |
| 6.5 grams             | 14.4                               | 14.1 | 13.8 | 13.5 | 13.3 | 13.0 | 12.7 | 12.5 | 12.3 | 12.0 | 11.8 | 11.6 | 11.4 | 11.2 | 11.0 | 10.8 | 10.6 | 10.5 | 10.3 | 10.1 |
| 6.6 grams             | 14.7                               | 14.3 | 14.0 | 13.7 | 13.5 | 13.2 | 12.9 | 12.7 | 12.4 | 12.2 | 12.0 | 11.8 | 11.6 | 11.4 | 11.2 | 11.0 | 10.8 | 10.6 | 10.5 | 10.3 |
| 6.7 grams             | 14.9                               | 14.6 | 14.2 | 13.9 | 13.7 | 13.4 | 13.1 | 12.9 | 12.6 | 12.4 | 12.2 | 12.0 | 11.7 | 11.5 | 11.3 | 11.2 | 11.0 | 10.8 | 10.6 | 10.5 |
| 6.8 grams             | 15.1                               | 14.8 | 14.5 | 14.2 | 13.9 | 13.6 | 13.3 | 13.1 | 12.8 | 12.6 | 12.4 | 12.1 | 11.9 | 11.7 | 11.5 | 11.3 | 11.1 | 11.0 | 10.8 | 10.6 |
| 6.9 grams             | 15.3                               | 15.0 | 14.7 | 14.4 | 14.1 | 13.8 | 13.5 | 13.3 | 13.0 | 12.8 | 12.5 | 12.3 | 12.1 | 11.9 | 11.7 | 11.5 | 11.3 | 11.1 | 10.9 | 10.8 |
| 7.0 grams             | 15.5                               | 15.2 | 14.9 | 14.6 | 14.3 | 14.0 | 13.7 | 13.5 | 13.2 | 13.0 | 12.7 | 12.5 | 12.3 | 12.1 | 11.9 | 11.7 | 11.5 | 11.3 | 11.1 | 10.9 |
| 7.1 grams             | 15.8                               | 15.4 | 15.1 | 14.8 | 14.5 | 14.2 | 13.9 | 13.6 | 13.4 | 13.1 | 12.9 | 12.7 | 12.4 | 12.2 | 12.0 | 11.8 | 11.6 | 11.4 | 11.3 | 11.1 |
| 7.2 grams             | 16.0                               | 15.6 | 15.3 | 15.0 | 14.7 | 14.4 | 14.1 | 13.8 | 13.6 | 13.3 | 13.1 | 12.8 | 12.6 | 12.4 | 12.2 | 12.0 | 11.8 | 11.6 | 11.4 | 11.2 |
| 7.3 grams             | 16.2                               | 15.9 | 15.5 | 15.2 | 14.9 | 14.6 | 14.3 | 14.0 | 13.8 | 13.5 | 13.3 | 13.0 | 12.8 | 12.6 | 12.4 | 12.2 | 12.0 | 11.8 | 11.6 | 11.4 |
| 7.4 grams             | 16.4                               | 16.1 | 15.7 | 15.4 | 15.1 | 14.8 | 14.5 | 14.2 | 14.0 | 13.7 | 13.4 | 13.2 | 13.0 | 12.7 | 12.5 | 12.3 | 12.1 | 11.9 | 11.7 | 11.6 |
| 7.5 grams             | 16.7                               | 16.3 | 15.9 | 15.6 | 15.3 | 15.0 | 14.7 | 14.4 | 14.1 | 13.8 | 13.6 | 13.4 | 13.1 | 12.9 | 12.7 | 12.5 | 12.3 | 12.1 | 11.9 | 11.7 |
| 7.6 grams             | 16.9                               | 16.5 | 16.2 | 15.8 | 15.5 | 15.2 | 14.9 | 14.6 | 14.3 | 14.1 | 13.8 | 13.6 | 13.3 | 13.1 | 12.9 | 12.7 | 12.4 | 12.2 | 12.1 | 11.7 |
| 7.7 grams             | 17.1                               | 16.7 | 16.4 | 16.0 | 15.7 | 15.4 | 15.1 | 14.8 | 14.5 | 14.2 | 14.0 | 13.7 | 13.5 | 13.3 | 13.0 | 12.8 | 12.6 | 12.4 | 12.2 | 12.0 |
| 7.8 grams             | 17.3                               | 16.9 | 16.6 | 16.2 | 15.9 | 15.6 | 15.3 | 15.0 | 14.7 | 14.4 | 14.2 | 13.9 | 13.7 | 13.4 | 13.2 | 13.0 | 12.8 | 12.6 | 12.4 | 12.2 |
| 7.9 grams             | 17.5                               | 17.2 | 16.8 | 16.4 | 16.1 | 15.8 | 15.5 | 15.2 | 14.9 | 14.6 | 14.4 | 14.1 | 13.8 | 13.6 | 13.4 | 13.2 | 12.9 | 12.7 | 12.5 | 12.3 |
| 8.0 grams             | 17.8                               | 17.4 | 17.0 | 16.6 | 16.3 | 16.0 | 15.7 | 15.4 | 15.1 | 14.8 | 14.5 | 14.3 | 14.0 | 13.8 | 13.6 | 13.4 | 13.2 | 12.9 | 12.7 | 12.5 |
| 8.1 grams             | 18.0                               | 17.6 | 17.2 | 16.9 | 16.5 | 16.2 | 15.9 | 15.6 | 15.3 | 15.0 | 14.7 | 14.5 | 14.2 | 14.0 | 13.7 | 13.5 | 13.3 | 13.1 | 12.8 | 12.5 |
| 8.2 grams             | 18.2                               | 17.8 | 17.4 | 17.1 | 16.7 | 16.4 | 16.1 | 15.8 | 15.5 | 15.2 | 14.9 | 14.6 | 14.4 | 14.1 | 13.9 | 13.7 | 13.4 | 13.2 | 13.0 | 12.8 |
| 8.3 grams             | 18.4                               | 18.0 | 17.6 | 17.3 | 16.9 | 16.6 | 16.3 | 16.0 | 15.7 | 15.4 | 15.1 | 14.8 | 14.6 | 14.3 | 14.1 | 13.8 | 13.6 | 13.4 | 13.2 | 13.0 |
| 8.4 grams             | 18.7                               | 18.3 | 17.9 | 17.5 | 17.1 | 16.8 | 16.5 | 16.1 | 15.8 | 15.5 | 15.3 | 15.0 | 14.7 | 14.5 | 14.2 | 14.0 | 13.8 | 13.5 | 13.3 | 13.1 |
| 8.5 grams             | 18.9                               | 18.5 | 18.1 | 17.7 | 17.3 | 17.0 | 16.7 | 16.3 | 16.0 | 15.7 | 15.4 | 15.2 | 14.9 | 14.6 | 14.4 | 14.2 | 13.9 | 13.7 | 13.5 | 13.3 |
| 8.6 grams             | 19.1                               | 18.7 | 18.3 | 17.9 | 17.5 | 17.2 | 16.9 | 16.5 | 16.2 | 15.9 | 15.6 | 15.3 | 15.1 | 14.8 | 14.6 | 14.3 | 14.1 | 13.9 | 13.6 | 13.4 |
| 8.7 grams             | 19.3                               | 18.9 | 18.5 | 18.1 | 17.7 | 17.4 | 17.0 | 16.7 | 16.4 | 16.1 | 15.8 | 15.5 | 15.3 | 15.0 | 14.7 | 14.5 | 14.3 | 14.0 | 13.8 | 13.6 |
| 8.8 grams             | 19.5                               | 19.1 | 18.7 | 18.3 | 17.9 | 17.6 | 17.2 | 16.9 | 16.6 | 16.3 | 16.0 | 15.7 | 15.4 | 15.2 | 14.9 | 14.7 | 14.4 | 14.2 | 14.0 | 13.8 |
| 8.9 grams             | 19.8                               | 19.3 | 18.9 | 18.5 | 18.2 | 17.8 | 17.4 | 17.1 | 16.8 | 16.5 | 16.2 | 15.9 | 15.6 | 15.3 | 15.1 | 14.8 | 14.6 | 14.3 | 14.1 | 13.9 |
| 9.0 grams             | 20.0                               | 19.6 | 19.1 | 18.7 | 18.4 | 18.0 | 17.6 | 17.3 | 17.0 | 16.7 | 16.4 | 16.1 | 15.8 | 15.5 | 15.2 | 15.0 | 14.7 | 14.5 | 14.3 | 14.1 |
| 9.1 grams             | 20.2                               | 19.8 | 19.4 | 18.9 | 18.6 | 18.2 | 17.8 | 17.5 | 17.2 | 16.8 | 16.5 | 16.2 | 16.0 | 15.7 | 15.4 | 15.2 | 14.9 | 14.7 | 14.4 | 14.2 |
| 9.2 grams             | 20.4                               | 20.0 | 19.6 | 19.2 | 18.8 | 18.4 | 18.0 | 17.7 | 17.3 | 17.0 | 16.7 | 16.4 | 16.1 | 15.8 | 15.5 | 15.3 | 15.1 | 14.8 | 14.6 | 14.4 |
| 9.3 grams             | 20.7                               | 20.2 | 19.8 | 19.4 | 19.0 | 18.6 | 18.2 | 17.9 | 17.5 | 17.2 | 16.9 | 16.6 | 16.3 | 16.0 | 15.8 | 15.5 | 15.2 | 15.0 | 14.8 | 14.5 |
| 9.4 grams             | 20.9                               | 20.4 | 20.0 | 19.6 | 19.2 | 18.8 | 18.4 | 18.1 | 17.7 | 17.4 | 17.1 | 16.8 | 16.5 | 16.2 | 15.9 | 15.7 | 15.4 | 15.2 | 14.9 | 14.7 |
| 9.5 grams             | 21.1                               | 20.6 | 20.2 | 19.8 | 19.4 | 19.0 | 18.6 | 18.3 | 17.9 | 17.6 | 17.3 | 17.0 | 16.7 | 16.4 | 16.1 | 15.8 | 15.6 | 15.3 | 15.1 | 14.8 |
| 9.6 grams             | 21.3                               | 20.9 | 20.4 | 20.0 | 19.6 | 19.2 | 18.8 | 18.5 | 18.1 | 17.8 | 17.4 | 17.1 | 16.8 | 16.5 | 16.3 | 16.0 | 15.7 | 15.5 | 15.2 | 15.0 |
| 9.7 grams             | 21.5                               | 21.1 | 20.6 | 20.2 | 19.8 | 19.4 | 19.0 | 18.6 | 18.3 | 18.0 | 17.6 | 17.3 | 17.0 | 16.7 | 16.4 | 16.2 | 15.9 | 15.6 | 15.4 | 15.1 |
| 9.8 grams             | 21.8                               | 21.3 | 20.8 | 20.4 | 20.0 | 19.6 | 19.2 | 18.8 | 18.5 | 18.1 | 17.8 | 17.5 | 17.2 | 16.9 | 16.6 | 16.3 | 16.1 | 15.8 | 15.5 | 15.3 |
| 9.9 grams             | 22.0                               | 21.5 | 21.1 | 20.6 | 20.2 | 19.8 | 19.4 | 19.0 | 18.7 | 18.3 | 18.0 | 17.7 | 17.4 | 17.1 | 16.8 | 16.5 | 16.2 | 16.0 | 15.7 | 15.5 |
| 10.0 grams            | 22.2                               | 21.7 | 21.3 | 20.8 | 20.4 | 20.0 | 19.6 | 19.2 | 18.9 | 18.5 | 18.2 | 17.8 | 17.5 | 17.2 | 16.9 | 16.7 | 16.4 | 16.1 | 15.9 | 15.6 |



TABLE I.—*Equivalent percentage of a sample of wheat, etc., when the weights of the sample analyzed and of the mechanical separation are given—Continued.*

| Weight of separation. | Weight of sample analyzed (grams). |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
|-----------------------|------------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
|                       | 25                                 | 26   | 27   | 28   | 29   | 30   | 31   | 32   | 33   | 34   | 35   | 36   | 37   | 38   | 39   | 40   | 41   | 42   | 43   | 44   |
| 10.1 grams.....       | 40.4                               | 38.8 | 37.4 | 36.1 | 34.8 | 33.7 | 32.6 | 31.6 | 30.6 | 29.7 | 28.8 | 28.0 | 27.3 | 26.6 | 25.9 | 25.2 | 24.6 | 24.0 | 23.5 | 22.9 |
| 10.2 grams.....       | 40.8                               | 39.2 | 37.8 | 36.4 | 35.2 | 34.0 | 32.9 | 31.9 | 30.9 | 30.0 | 29.1 | 28.3 | 27.6 | 26.8 | 26.1 | 25.5 | 24.9 | 24.3 | 23.7 | 23.2 |
| 10.3 grams.....       | 41.2                               | 39.6 | 38.1 | 36.8 | 35.5 | 34.3 | 33.2 | 32.2 | 31.2 | 30.3 | 29.4 | 28.6 | 27.8 | 27.1 | 26.4 | 25.7 | 25.1 | 24.5 | 23.9 | 23.4 |
| 10.4 grams.....       | 41.6                               | 40.0 | 38.5 | 37.1 | 35.9 | 34.7 | 33.5 | 32.5 | 31.5 | 30.6 | 29.7 | 28.9 | 28.1 | 27.4 | 26.7 | 26.0 | 25.4 | 24.8 | 24.2 | 23.6 |
| 10.5 grams.....       | 42.0                               | 40.4 | 38.9 | 37.5 | 36.2 | 35.0 | 33.9 | 32.8 | 31.8 | 30.9 | 30.0 | 29.2 | 28.4 | 27.6 | 26.9 | 26.2 | 25.6 | 25.0 | 24.4 | 23.9 |
| 10.6 grams.....       | 42.4                               | 40.8 | 39.2 | 37.8 | 36.5 | 35.3 | 34.2 | 33.1 | 32.1 | 31.2 | 30.3 | 29.4 | 28.6 | 27.9 | 27.2 | 26.5 | 25.8 | 25.2 | 24.6 | 24.1 |
| 10.7 grams.....       | 42.8                               | 41.1 | 39.6 | 38.2 | 36.9 | 35.7 | 34.5 | 33.4 | 32.4 | 31.5 | 30.6 | 29.7 | 28.9 | 28.1 | 27.4 | 26.7 | 26.0 | 25.4 | 24.8 | 24.3 |
| 10.8 grams.....       | 43.2                               | 41.5 | 40.0 | 38.6 | 37.2 | 36.0 | 34.8 | 33.7 | 32.7 | 31.8 | 30.9 | 30.0 | 29.2 | 28.4 | 27.7 | 27.0 | 26.3 | 25.7 | 25.1 | 24.5 |
| 10.9 grams.....       | 43.6                               | 41.9 | 40.4 | 38.9 | 37.6 | 36.3 | 35.2 | 34.1 | 33.0 | 32.0 | 31.1 | 30.3 | 29.4 | 28.7 | 27.9 | 27.2 | 26.6 | 25.9 | 25.3 | 24.8 |
| 11.0 grams.....       | 44.0                               | 42.3 | 40.7 | 39.3 | 37.9 | 36.7 | 35.5 | 34.4 | 33.3 | 32.3 | 31.4 | 30.5 | 29.7 | 28.9 | 28.2 | 27.5 | 26.8 | 26.2 | 25.6 | 25.0 |
| 11.1 grams.....       | 44.4                               | 42.7 | 41.1 | 39.6 | 38.3 | 37.0 | 35.8 | 34.7 | 33.6 | 32.6 | 31.7 | 30.8 | 30.0 | 29.2 | 28.5 | 27.7 | 27.1 | 26.4 | 25.8 | 25.2 |
| 11.2 grams.....       | 44.8                               | 43.1 | 41.5 | 40.0 | 38.6 | 37.3 | 36.1 | 35.0 | 33.9 | 32.9 | 32.0 | 31.1 | 30.3 | 29.4 | 28.7 | 27.9 | 27.2 | 26.6 | 25.9 | 25.4 |
| 11.3 grams.....       | 45.2                               | 43.5 | 41.8 | 40.3 | 39.0 | 37.7 | 36.4 | 35.3 | 34.2 | 33.2 | 32.3 | 31.4 | 30.5 | 29.7 | 29.0 | 28.2 | 27.6 | 26.9 | 26.3 | 25.7 |
| 11.4 grams.....       | 45.6                               | 43.8 | 42.2 | 40.7 | 39.3 | 38.0 | 36.8 | 35.6 | 34.5 | 33.5 | 32.6 | 31.7 | 30.8 | 30.0 | 29.2 | 28.5 | 27.8 | 27.1 | 26.5 | 25.9 |
| 11.5 grams.....       | 46.0                               | 44.2 | 42.6 | 41.1 | 39.6 | 38.3 | 37.1 | 35.9 | 34.8 | 33.8 | 32.9 | 31.9 | 31.0 | 30.2 | 29.5 | 28.7 | 28.0 | 27.4 | 26.7 | 26.1 |
| 11.6 grams.....       | 46.4                               | 44.6 | 43.0 | 41.4 | 40.0 | 38.7 | 37.4 | 36.2 | 35.1 | 34.1 | 33.2 | 32.2 | 31.3 | 30.5 | 29.7 | 29.0 | 28.3 | 27.6 | 27.0 | 26.4 |
| 11.7 grams.....       | 46.8                               | 45.0 | 43.3 | 41.8 | 40.3 | 39.0 | 37.7 | 36.5 | 35.4 | 34.4 | 33.4 | 32.5 | 31.6 | 30.8 | 30.0 | 29.2 | 28.5 | 27.8 | 27.2 | 26.6 |
| 11.8 grams.....       | 47.2                               | 45.4 | 43.7 | 42.1 | 40.7 | 39.3 | 38.1 | 36.9 | 35.7 | 34.7 | 33.7 | 32.8 | 31.9 | 31.0 | 30.2 | 29.5 | 28.8 | 28.1 | 27.4 | 26.8 |
| 11.9 grams.....       | 47.6                               | 45.8 | 44.1 | 42.5 | 41.0 | 39.7 | 38.4 | 37.2 | 36.1 | 35.0 | 34.0 | 33.0 | 32.2 | 31.3 | 30.5 | 29.7 | 29.0 | 28.3 | 27.7 | 27.0 |
| 12.0 grams.....       | 48.0                               | 46.1 | 44.4 | 42.8 | 41.4 | 40.0 | 38.7 | 37.5 | 36.4 | 35.3 | 34.3 | 33.3 | 32.4 | 31.5 | 30.6 | 30.0 | 29.3 | 28.6 | 27.9 | 27.3 |
| 12.1 grams.....       | 48.4                               | 46.5 | 44.8 | 43.2 | 41.7 | 40.3 | 39.0 | 37.8 | 36.6 | 35.5 | 34.5 | 33.6 | 32.7 | 31.8 | 31.0 | 30.2 | 29.5 | 28.8 | 28.1 | 27.5 |
| 12.2 grams.....       | 48.8                               | 46.9 | 45.2 | 43.6 | 42.1 | 40.7 | 39.3 | 38.1 | 37.0 | 35.9 | 34.8 | 33.9 | 33.0 | 32.1 | 31.3 | 30.5 | 29.7 | 29.0 | 28.4 | 27.7 |
| 12.3 grams.....       | 49.2                               | 47.3 | 45.5 | 43.9 | 42.4 | 41.0 | 39.7 | 38.4 | 37.3 | 36.2 | 35.1 | 34.2 | 33.2 | 32.4 | 31.5 | 30.7 | 29.9 | 29.3 | 28.6 | 27.9 |
| 12.4 grams.....       | 49.6                               | 47.7 | 45.9 | 44.3 | 42.7 | 41.3 | 40.0 | 38.7 | 37.6 | 36.5 | 35.4 | 34.4 | 33.5 | 32.6 | 31.8 | 31.0 | 30.2 | 29.5 | 28.8 | 28.2 |
| 12.5 grams.....       | 50.0                               | 48.1 | 46.3 | 44.6 | 43.1 | 41.7 | 40.3 | 39.1 | 37.9 | 36.8 | 35.7 | 34.7 | 33.8 | 32.9 | 32.0 | 31.2 | 30.5 | 29.8 | 29.1 | 28.4 |
| 12.6 grams.....       | 50.4                               | 48.5 | 46.7 | 45.0 | 43.4 | 42.0 | 40.6 | 39.3 | 38.2 | 37.0 | 36.0 | 35.0 | 34.0 | 33.1 | 32.3 | 31.5 | 30.7 | 30.0 | 29.3 | 28.6 |
| 12.7 grams.....       | 50.8                               | 48.8 | 47.0 | 45.3 | 43.8 | 42.3 | 41.0 | 39.7 | 38.5 | 37.3 | 36.3 | 35.3 | 34.3 | 33.4 | 32.6 | 31.7 | 31.0 | 30.2 | 29.5 | 28.9 |
| 12.8 grams.....       | 51.2                               | 49.2 | 47.4 | 45.7 | 44.1 | 42.7 | 41.3 | 40.0 | 38.8 | 37.6 | 36.6 | 35.5 | 34.6 | 33.7 | 32.8 | 32.0 | 31.2 | 30.5 | 29.8 | 29.1 |
| 12.9 grams.....       | 51.6                               | 49.6 | 47.8 | 46.1 | 44.5 | 43.0 | 41.6 | 40.3 | 39.1 | 37.9 | 36.9 | 35.8 | 34.9 | 33.9 | 33.1 | 32.2 | 31.5 | 30.7 | 30.0 | 29.3 |
| 13.0 grams.....       | 52.0                               | 50.0 | 48.1 | 46.4 | 44.8 | 43.3 | 41.9 | 40.6 | 39.3 | 38.2 | 37.1 | 36.1 | 35.1 | 34.2 | 33.3 | 32.5 | 31.7 | 30.9 | 30.2 | 29.5 |
| 13.1 grams.....       | 52.4                               | 50.4 | 48.5 | 46.8 | 45.2 | 43.7 | 42.2 | 40.9 | 39.7 | 38.5 | 37.4 | 36.4 | 35.4 | 34.5 | 33.6 | 32.7 | 31.9 | 31.2 | 30.5 | 29.8 |
| 13.2 grams.....       | 52.8                               | 50.8 | 48.9 | 47.1 | 45.5 | 44.0 | 42.6 | 41.2 | 40.0 | 38.8 | 37.7 | 36.7 | 35.7 | 34.7 | 33.8 | 33.0 | 32.2 | 31.4 | 30.7 | 30.0 |
| 13.3 grams.....       | 53.2                               | 51.1 | 49.2 | 47.5 | 45.9 | 44.3 | 42.9 | 41.6 | 40.3 | 39.1 | 38.0 | 36.9 | 35.9 | 35.0 | 34.1 | 33.2 | 32.4 | 31.7 | 30.9 | 30.2 |
| 13.4 grams.....       | 53.6                               | 51.5 | 49.6 | 47.8 | 46.2 | 44.6 | 43.2 | 41.9 | 40.6 | 39.3 | 38.2 | 37.2 | 36.2 | 35.3 | 34.3 | 33.5 | 32.7 | 31.9 | 31.2 | 30.4 |
| 13.5 grams.....       | 54.0                               | 51.9 | 50.0 | 48.2 | 46.5 | 44.9 | 43.5 | 42.2 | 40.9 | 39.7 | 38.6 | 37.5 | 36.5 | 35.5 | 34.6 | 33.7 | 32.9 | 32.1 | 31.4 | 30.7 |
| 13.6 grams.....       | 54.4                               | 52.3 | 50.4 | 48.6 | 46.9 | 45.3 | 43.9 | 42.5 | 41.2 | 40.0 | 38.8 | 37.8 | 36.7 | 35.8 | 34.9 | 34.0 | 33.2 | 32.4 | 31.6 | 30.9 |
| 13.7 grams.....       | 54.8                               | 52.7 | 50.7 | 48.9 | 47.2 | 45.7 | 44.2 | 42.8 | 41.5 | 40.3 | 39.1 | 38.0 | 37.0 | 36.0 | 35.1 | 34.2 | 33.4 | 32.6 | 31.9 | 31.1 |
| 13.8 grams.....       | 55.2                               | 53.1 | 51.1 | 49.3 | 47.6 | 46.0 | 44.5 | 43.1 | 41.8 | 40.6 | 39.3 | 38.3 | 37.3 | 36.3 | 35.4 | 34.5 | 33.6 | 32.8 | 32.1 | 31.4 |
| 13.9 grams.....       | 55.6                               | 53.5 | 51.5 | 49.6 | 47.9 | 46.3 | 44.8 | 43.4 | 42.1 | 40.9 | 39.7 | 38.6 | 37.6 | 36.6 | 35.6 | 34.7 | 33.9 | 33.1 | 32.3 | 31.6 |
| 14.0 grams.....       | 56.0                               | 53.8 | 51.8 | 50.0 | 48.3 | 46.7 | 45.2 | 43.7 | 42.4 | 41.2 | 40.0 | 38.9 | 37.8 | 36.8 | 35.9 | 35.0 | 34.1 | 33.3 | 32.5 | 31.8 |
| 14.1 grams.....       | 56.4                               | 54.2 | 52.2 | 50.3 | 48.6 | 47.0 | 45.5 | 44.1 | 42.7 | 41.5 | 40.3 | 39.2 | 38.1 | 37.1 | 36.1 | 35.2 | 34.4 | 33.6 | 32.8 | 32.0 |
| 14.2 grams.....       | 56.8                               | 54.6 | 52.6 | 50.7 | 49.0 | 47.3 | 45.8 | 44.4 | 43.0 | 41.8 | 40.6 | 39.4 | 38.4 | 37.4 | 36.4 | 35.5 | 34.6 | 33.8 | 33.0 | 32.3 |
| 14.3 grams.....       | 57.2                               | 55.0 | 53.0 | 51.1 | 49.3 | 47.7 | 46.1 | 44.7 | 43.3 | 42.0 | 40.8 | 39.7 | 38.6 | 37.6 | 36.6 | 35.7 | 34.8 | 34.0 | 33.2 | 32.5 |
| 14.4 grams.....       | 57.6                               | 55.4 | 53.3 | 51.4 | 49.6 | 48.0 | 46.4 | 45.0 | 43.6 | 42.3 | 41.1 | 40.0 | 38.9 | 37.9 | 36.9 | 36.0 | 35.1 | 34.3 | 33.5 | 32.7 |
| 14.5 grams.....       | 58.0                               | 55.8 | 53.7 | 51.8 | 50.0 | 48.3 | 46.8 | 45.2 | 43.9 | 42.6 | 41.4 | 40.3 | 39.2 | 38.1 | 37.2 | 36.2 | 35.4 | 34.5 | 33.7 | 32.9 |
| 14.6 grams.....       | 58.4                               | 56.1 | 54.1 | 52.1 | 50.3 | 48.7 | 47.1 | 45.6 | 44.2 | 42.9 | 41.7 | 40.5 | 39.4 | 38.4 | 37.4 | 36.5 | 35.6 | 34.8 | 33.9 | 33.2 |
| 14.7 grams.....       | 58.8                               | 56.5 | 54.4 | 52.5 | 50.7 | 49.0 | 47.4 | 45.9 | 44.5 | 43.2 | 42.0 | 40.8 | 39.7 | 38.7 | 37.7 | 36.7 | 35.8 | 35.0 | 34.2 | 33.4 |
| 14.8 grams.....       | 59.2                               | 56.9 | 54.8 | 52.8 | 51.0 | 49.3 | 47.7 | 46.2 | 44.8 | 43.5 | 42.3 | 41.1 | 40.0 | 38.9 | 37.9 | 36.9 | 36.0 | 35.2 | 34.4 | 33.6 |
| 14.9 grams.....       | 59.6                               | 57.3 | 55.2 | 53.2 | 51.4 | 49.7 | 48.1 | 46.6 | 45.1 | 43.8 | 42.6 | 41.4 | 40.3 | 39.2 | 38.2 | 37.2 | 36.3 | 35.5 | 34.6 | 33.9 |
| 15.0 grams.....       | 60.0                               | 57.7 | 55.5 | 53.6 | 51.7 | 50.0 | 48.4 | 46.9 | 45.4 | 44.1 | 42.8 | 41.7 | 40.5 | 39.5 | 38.5 | 37.5 | 36.6 | 35.7 | 34.9 | 34.1 |



TABLE I.—*Equivalent percentage of a sample of wheat, etc., when the weights of the sample analyzed and of the mechanical separation are given—Continued.*

| Weight of separation. | Weight of sample analyzed (grams). |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
|-----------------------|------------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
|                       | 45                                 | 46   | 47   | 48   | 49   | 50   | 51   | 52   | 53   | 54   | 55   | 56   | 57   | 58   | 59   | 60   | 61   |
| 10.1 grams            | 22.4                               | 21.9 | 21.5 | 21.0 | 20.6 | 20.2 | 19.8 | 19.4 | 19.0 | 18.7 | 18.4 | 18.0 | 17.7 | 17.4 | 17.1 | 16.8 | 16.5 |
| 10.2 grams            | 22.7                               | 22.2 | 21.7 | 21.2 | 20.8 | 20.4 | 20.0 | 19.6 | 19.2 | 18.9 | 18.5 | 18.2 | 17.9 | 17.6 | 17.3 | 17.0 | 16.7 |
| 10.3 grams            | 22.9                               | 22.4 | 21.9 | 21.4 | 21.0 | 20.6 | 20.2 | 19.8 | 19.4 | 19.1 | 18.7 | 18.4 | 18.1 | 17.7 | 17.4 | 17.2 | 16.9 |
| 10.4 grams            | 23.1                               | 22.6 | 22.1 | 21.7 | 21.2 | 20.8 | 20.4 | 20.0 | 19.6 | 19.2 | 18.9 | 18.6 | 18.3 | 17.9 | 17.6 | 17.3 | 17.0 |
| 10.5 grams            | 23.3                               | 22.8 | 22.3 | 21.9 | 21.4 | 21.0 | 20.6 | 20.2 | 19.8 | 19.4 | 19.1 | 18.7 | 18.4 | 18.1 | 17.8 | 17.5 | 17.2 |
| 10.6 grams            | 23.5                               | 23.0 | 22.5 | 22.1 | 21.6 | 21.2 | 20.8 | 20.4 | 20.0 | 19.6 | 19.3 | 18.9 | 18.6 | 18.3 | 18.0 | 17.7 | 17.4 |
| 10.7 grams            | 23.8                               | 23.3 | 22.8 | 22.3 | 21.8 | 21.4 | 21.0 | 20.6 | 20.2 | 19.8 | 19.4 | 19.1 | 18.8 | 18.4 | 18.1 | 17.8 | 17.5 |
| 10.8 grams            | 24.0                               | 23.5 | 23.0 | 22.5 | 22.0 | 21.6 | 21.2 | 20.8 | 20.4 | 20.0 | 19.6 | 19.3 | 18.9 | 18.6 | 18.3 | 18.0 | 17.7 |
| 10.9 grams            | 24.2                               | 23.7 | 23.2 | 22.7 | 22.2 | 21.8 | 21.4 | 21.0 | 20.6 | 20.2 | 19.8 | 19.5 | 19.1 | 18.8 | 18.5 | 18.2 | 17.9 |
| 11.0 grams            | 24.4                               | 23.9 | 23.4 | 22.9 | 22.4 | 22.0 | 21.6 | 21.1 | 20.7 | 20.4 | 20.0 | 19.6 | 19.3 | 19.0 | 18.6 | 18.3 | 18.0 |
| 11.1 grams            | 24.7                               | 24.1 | 23.6 | 23.1 | 22.6 | 22.2 | 21.8 | 21.3 | 20.9 | 20.5 | 20.2 | 19.8 | 19.5 | 19.1 | 18.8 | 18.5 | 18.2 |
| 11.2 grams            | 24.9                               | 24.3 | 23.8 | 23.3 | 22.8 | 22.4 | 22.0 | 21.5 | 21.1 | 20.7 | 20.4 | 20.0 | 19.6 | 19.3 | 19.0 | 18.7 | 18.4 |
| 11.3 grams            | 25.1                               | 24.6 | 24.0 | 23.5 | 23.1 | 22.6 | 22.1 | 21.7 | 21.3 | 20.9 | 20.5 | 20.2 | 19.8 | 19.5 | 19.1 | 18.8 | 18.5 |
| 11.4 grams            | 25.3                               | 24.8 | 24.2 | 23.7 | 23.3 | 22.8 | 22.3 | 21.9 | 21.5 | 21.1 | 20.7 | 20.3 | 20.0 | 19.6 | 19.3 | 19.0 | 18.7 |
| 11.5 grams            | 25.5                               | 25.0 | 24.5 | 23.9 | 23.5 | 23.0 | 22.5 | 22.1 | 21.7 | 21.3 | 20.9 | 20.5 | 20.2 | 19.8 | 19.5 | 19.2 | 18.8 |
| 11.6 grams            | 25.8                               | 25.2 | 24.7 | 24.2 | 23.7 | 23.2 | 22.7 | 22.3 | 21.9 | 21.5 | 21.1 | 20.7 | 20.3 | 20.0 | 19.7 | 19.3 | 19.0 |
| 11.7 grams            | 26.0                               | 25.4 | 24.9 | 24.4 | 23.9 | 23.4 | 22.9 | 22.5 | 22.1 | 21.7 | 21.3 | 20.9 | 20.5 | 20.2 | 19.8 | 19.5 | 19.2 |
| 11.8 grams            | 26.2                               | 25.6 | 25.1 | 24.6 | 24.1 | 23.6 | 23.1 | 22.7 | 22.3 | 21.8 | 21.4 | 21.1 | 20.7 | 20.3 | 20.0 | 19.7 | 19.3 |
| 11.9 grams            | 26.4                               | 25.9 | 25.3 | 24.8 | 24.3 | 23.8 | 23.3 | 22.9 | 22.4 | 22.0 | 21.6 | 21.2 | 20.9 | 20.5 | 20.2 | 19.8 | 19.5 |
| 12.0 grams            | 26.7                               | 26.1 | 25.5 | 25.0 | 24.5 | 24.0 | 23.5 | 23.0 | 22.6 | 22.1 | 21.7 | 21.3 | 21.0 | 20.7 | 20.3 | 20.0 | 19.7 |
| 12.1 grams            | 26.9                               | 26.3 | 25.7 | 25.2 | 24.7 | 24.2 | 23.7 | 23.3 | 22.8 | 22.4 | 22.0 | 21.6 | 21.2 | 20.9 | 20.5 | 20.2 | 19.8 |
| 12.2 grams            | 27.1                               | 26.5 | 25.9 | 25.4 | 24.9 | 24.4 | 23.9 | 23.5 | 23.0 | 22.6 | 22.2 | 21.8 | 21.4 | 21.1 | 20.7 | 20.3 | 20.0 |
| 12.3 grams            | 27.3                               | 26.7 | 26.2 | 25.6 | 25.1 | 24.6 | 24.1 | 23.6 | 23.2 | 22.8 | 22.4 | 22.0 | 21.6 | 21.2 | 20.8 | 20.5 | 20.2 |
| 12.4 grams            | 27.5                               | 26.9 | 26.4 | 25.8 | 25.3 | 24.8 | 24.3 | 23.8 | 23.4 | 23.0 | 22.5 | 22.1 | 21.7 | 21.4 | 21.0 | 20.7 | 20.3 |
| 12.5 grams            | 27.8                               | 27.2 | 26.6 | 26.0 | 25.5 | 25.0 | 24.5 | 24.0 | 23.6 | 23.1 | 22.7 | 22.3 | 21.9 | 21.5 | 21.2 | 20.8 | 20.5 |
| 12.6 grams            | 28.0                               | 27.4 | 26.8 | 26.2 | 25.7 | 25.2 | 24.7 | 24.2 | 23.8 | 23.3 | 22.9 | 22.5 | 22.1 | 21.7 | 21.3 | 21.0 | 20.6 |
| 12.7 grams            | 28.2                               | 27.6 | 27.0 | 26.4 | 25.9 | 25.4 | 24.9 | 24.4 | 24.0 | 23.5 | 23.1 | 22.7 | 22.3 | 21.9 | 21.5 | 21.2 | 20.8 |
| 12.8 grams            | 28.4                               | 27.8 | 27.2 | 26.6 | 26.1 | 25.6 | 25.1 | 24.6 | 24.1 | 23.7 | 23.3 | 22.8 | 22.4 | 22.1 | 21.7 | 21.3 | 21.0 |
| 12.9 grams            | 28.7                               | 28.0 | 27.4 | 26.8 | 26.3 | 25.8 | 25.3 | 24.8 | 24.3 | 23.9 | 23.4 | 23.0 | 22.6 | 22.2 | 21.9 | 21.5 | 21.2 |
| 13.0 grams            | 28.9                               | 28.3 | 27.6 | 27.1 | 26.5 | 26.0 | 25.5 | 25.0 | 24.5 | 24.1 | 23.6 | 23.2 | 22.8 | 22.4 | 22.0 | 21.7 | 21.3 |
| 13.1 grams            | 29.1                               | 28.5 | 27.9 | 27.3 | 26.7 | 26.2 | 25.7 | 25.2 | 24.7 | 24.2 | 23.8 | 23.4 | 23.0 | 22.6 | 22.2 | 21.8 | 21.5 |
| 13.2 grams            | 29.3                               | 28.7 | 28.1 | 27.5 | 26.9 | 26.4 | 25.9 | 25.4 | 24.9 | 24.4 | 24.0 | 23.6 | 23.1 | 22.7 | 22.3 | 21.9 | 21.6 |
| 13.3 grams            | 29.5                               | 28.9 | 28.3 | 27.7 | 27.1 | 26.6 | 26.1 | 25.6 | 25.1 | 24.6 | 24.2 | 23.7 | 23.3 | 22.9 | 22.5 | 22.2 | 21.8 |
| 13.4 grams            | 29.8                               | 29.1 | 28.5 | 27.9 | 27.3 | 26.8 | 26.3 | 25.8 | 25.3 | 24.8 | 24.4 | 23.9 | 23.5 | 23.1 | 22.7 | 22.3 | 22.0 |
| 13.5 grams            | 30.0                               | 29.3 | 28.7 | 28.1 | 27.5 | 27.0 | 26.5 | 26.0 | 25.5 | 25.0 | 24.5 | 24.1 | 23.7 | 23.3 | 22.9 | 22.5 | 22.1 |
| 13.6 grams            | 30.2                               | 29.6 | 28.9 | 28.3 | 27.7 | 27.2 | 26.7 | 26.1 | 25.7 | 25.2 | 24.7 | 24.3 | 23.8 | 23.4 | 23.0 | 22.6 | 22.3 |
| 13.7 grams            | 30.4                               | 29.8 | 29.1 | 28.5 | 27.9 | 27.4 | 26.9 | 26.3 | 25.8 | 25.4 | 24.9 | 24.5 | 24.0 | 23.6 | 23.2 | 22.8 | 22.4 |
| 13.8 grams            | 30.7                               | 30.0 | 29.4 | 28.7 | 28.2 | 27.6 | 27.0 | 26.5 | 26.0 | 25.5 | 25.1 | 24.6 | 24.2 | 23.8 | 23.4 | 23.0 | 22.6 |
| 13.9 grams            | 30.9                               | 30.2 | 29.6 | 28.9 | 28.3 | 27.7 | 27.2 | 26.7 | 26.2 | 25.7 | 25.3 | 24.8 | 24.4 | 24.0 | 23.5 | 23.1 | 22.7 |
| 14.0 grams            | 31.1                               | 30.4 | 29.8 | 29.2 | 28.6 | 28.0 | 27.4 | 26.9 | 26.4 | 25.9 | 25.4 | 25.0 | 24.6 | 24.1 | 23.7 | 23.3 | 22.9 |
| 14.1 grams            | 31.3                               | 30.6 | 30.0 | 29.4 | 28.8 | 28.2 | 27.6 | 27.1 | 26.6 | 26.1 | 25.6 | 25.2 | 24.7 | 24.3 | 23.9 | 23.5 | 23.1 |
| 14.2 grams            | 31.5                               | 30.9 | 30.2 | 29.6 | 29.0 | 28.4 | 27.8 | 27.3 | 26.8 | 26.3 | 25.8 | 25.3 | 24.9 | 24.5 | 24.1 | 23.7 | 23.3 |
| 14.3 grams            | 31.8                               | 31.1 | 30.4 | 29.8 | 29.2 | 28.6 | 28.0 | 27.5 | 27.0 | 26.5 | 26.0 | 25.5 | 25.1 | 24.6 | 24.2 | 23.8 | 23.4 |
| 14.4 grams            | 32.0                               | 31.3 | 30.6 | 30.0 | 29.4 | 28.8 | 28.2 | 27.7 | 27.2 | 26.7 | 26.2 | 25.7 | 25.3 | 24.8 | 24.4 | 24.0 | 23.6 |
| 14.5 grams            | 32.2                               | 31.5 | 30.8 | 30.2 | 29.6 | 29.0 | 28.4 | 27.9 | 27.3 | 26.8 | 26.3 | 25.8 | 25.4 | 24.9 | 24.5 | 24.1 | 23.7 |
| 14.6 grams            | 32.4                               | 31.7 | 31.1 | 30.4 | 29.8 | 29.2 | 28.6 | 28.1 | 27.5 | 27.0 | 26.5 | 26.1 | 25.6 | 25.2 | 24.7 | 24.3 | 23.9 |
| 14.7 grams            | 32.7                               | 31.9 | 31.3 | 30.6 | 30.0 | 29.4 | 28.8 | 28.3 | 27.7 | 27.2 | 26.7 | 26.2 | 25.7 | 25.3 | 24.9 | 24.5 | 24.1 |
| 14.8 grams            | 32.9                               | 32.2 | 31.5 | 30.8 | 30.2 | 29.6 | 29.0 | 28.5 | 27.9 | 27.4 | 26.9 | 26.4 | 26.0 | 25.5 | 25.1 | 24.7 | 24.3 |
| 14.9 grams            | 33.1                               | 32.4 | 31.7 | 31.0 | 30.4 | 29.8 | 29.2 | 28.6 | 28.1 | 27.6 | 27.1 | 26.6 | 26.1 | 25.7 | 25.2 | 24.8 | 24.4 |
| 15.0 grams            | 33.3                               | 32.6 | 31.9 | 31.2 | 30.6 | 30.0 | 29.4 | 28.8 | 28.3 | 27.8 | 27.3 | 26.8 | 26.3 | 25.9 | 25.4 | 25.0 | 24.6 |

TABLE I.—*Equivalent percentage of a sample of wheat, etc., when the weights of the sample analyzed and of the mechanical separation are given—Continued.*

| Weight of separation. | Weight of sample analyzed (grams). |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
|-----------------------|------------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
|                       | 25                                 | 26   | 27   | 28   | 29   | 30   | 31   | 32   | 33   | 34   | 35   | 36   | 37   | 38   | 39   | 40   | 41   | 42   | 43   | 44   |
| 15.1 grams.....       | 60.4                               | 58.1 | 55.9 | 53.9 | 52.1 | 50.3 | 48.7 | 47.2 | 45.7 | 44.4 | 43.1 | 41.9 | 40.8 | 39.7 | 38.7 | 37.7 | 36.8 | 35.9 | 35.1 | 34.3 |
| 15.2 grams.....       | 60.8                               | 58.5 | 56.3 | 54.3 | 52.4 | 50.7 | 49.0 | 47.5 | 46.1 | 44.7 | 43.4 | 42.2 | 41.1 | 40.0 | 39.0 | 38.0 | 37.1 | 36.2 | 35.3 | 34.5 |
| 15.3 grams.....       | 61.2                               | 58.8 | 56.7 | 54.6 | 52.7 | 51.0 | 49.3 | 47.8 | 46.4 | 45.0 | 43.7 | 42.5 | 41.3 | 40.3 | 39.2 | 38.2 | 37.3 | 36.4 | 35.6 | 34.8 |
| 15.4 grams.....       | 61.6                               | 59.2 | 57.0 | 55.0 | 53.1 | 51.3 | 49.7 | 48.1 | 46.7 | 45.3 | 44.0 | 42.8 | 41.6 | 40.5 | 39.5 | 38.5 | 37.6 | 36.7 | 35.8 | 35.0 |
| 15.5 grams.....       | 62.0                               | 59.6 | 57.4 | 55.3 | 53.4 | 51.7 | 50.0 | 48.4 | 47.0 | 45.6 | 44.3 | 43.0 | 41.9 | 40.8 | 39.7 | 38.7 | 37.8 | 36.9 | 36.0 | 35.2 |
| 15.6 grams.....       | 62.4                               | 60.0 | 57.8 | 55.7 | 53.8 | 52.0 | 50.3 | 48.7 | 47.3 | 45.9 | 44.6 | 43.3 | 42.2 | 41.0 | 40.0 | 39.0 | 38.0 | 37.1 | 36.3 | 35.4 |
| 15.7 grams.....       | 62.8                               | 60.4 | 58.1 | 56.1 | 54.1 | 52.3 | 50.6 | 49.1 | 47.6 | 46.2 | 44.8 | 43.6 | 42.4 | 41.3 | 40.2 | 39.2 | 38.3 | 37.4 | 36.5 | 35.7 |
| 15.8 grams.....       | 63.2                               | 60.8 | 58.5 | 56.4 | 54.5 | 52.7 | 51.0 | 49.4 | 47.9 | 46.5 | 45.1 | 43.9 | 42.7 | 41.6 | 40.5 | 39.5 | 38.5 | 37.6 | 36.7 | 35.9 |
| 15.9 grams.....       | 63.6                               | 61.1 | 58.9 | 56.8 | 54.8 | 53.0 | 51.3 | 49.7 | 48.2 | 46.8 | 45.4 | 44.2 | 43.0 | 41.9 | 40.8 | 39.7 | 38.8 | 37.8 | 37.0 | 36.1 |
| 16.0 grams.....       | 64.0                               | 61.5 | 59.2 | 57.1 | 55.2 | 53.3 | 51.6 | 50.0 | 48.5 | 47.0 | 45.7 | 44.4 | 43.2 | 42.1 | 41.0 | 40.0 | 39.0 | 38.1 | 37.2 | 36.4 |
| 16.1 grams.....       | 64.4                               | 61.9 | 59.6 | 57.5 | 55.5 | 53.7 | 51.9 | 50.3 | 48.8 | 47.3 | 46.0 | 44.7 | 43.5 | 42.4 | 41.3 | 40.2 | 39.3 | 38.3 | 37.4 | 36.6 |
| 16.2 grams.....       | 64.8                               | 62.3 | 60.0 | 57.8 | 55.9 | 54.0 | 52.2 | 50.6 | 49.1 | 47.6 | 46.3 | 45.0 | 43.8 | 42.6 | 41.5 | 40.5 | 39.5 | 38.6 | 37.7 | 36.8 |
| 16.3 grams.....       | 65.2                               | 62.7 | 60.4 | 58.2 | 56.2 | 54.3 | 52.6 | 50.9 | 49.4 | 47.9 | 46.6 | 45.3 | 44.0 | 42.9 | 41.8 | 40.7 | 39.7 | 38.8 | 37.9 | 37.0 |
| 16.4 grams.....       | 65.6                               | 63.1 | 60.7 | 58.6 | 56.5 | 54.7 | 52.9 | 51.2 | 49.7 | 48.2 | 46.8 | 45.5 | 44.3 | 43.1 | 42.0 | 41.0 | 40.0 | 39.0 | 38.1 | 37.3 |
| 16.5 grams.....       | 66.0                               | 63.5 | 61.1 | 58.9 | 56.9 | 55.0 | 53.2 | 51.6 | 50.0 | 48.5 | 47.1 | 45.8 | 44.6 | 43.4 | 42.3 | 41.2 | 40.2 | 39.3 | 38.4 | 37.5 |
| 16.6 grams.....       | 66.4                               | 63.8 | 61.5 | 59.3 | 57.2 | 55.3 | 53.5 | 51.9 | 50.3 | 48.8 | 47.4 | 46.1 | 44.9 | 43.7 | 42.6 | 41.5 | 40.5 | 39.5 | 38.6 | 37.7 |
| 16.7 grams.....       | 66.8                               | 64.2 | 61.8 | 59.6 | 57.6 | 55.7 | 53.9 | 52.2 | 50.6 | 49.1 | 47.7 | 46.4 | 45.1 | 43.9 | 42.8 | 41.7 | 40.7 | 39.8 | 38.8 | 37.9 |
| 16.8 grams.....       | 67.2                               | 64.6 | 62.2 | 60.0 | 57.9 | 56.0 | 54.2 | 52.5 | 50.9 | 49.4 | 48.0 | 46.7 | 45.4 | 44.2 | 43.1 | 42.0 | 41.0 | 40.0 | 39.1 | 38.2 |
| 16.9 grams.....       | 67.6                               | 65.0 | 62.6 | 60.3 | 58.3 | 56.3 | 54.5 | 52.8 | 51.2 | 49.7 | 48.3 | 46.9 | 45.7 | 44.5 | 43.3 | 42.2 | 41.2 | 40.2 | 39.3 | 38.4 |
| 17.0 grams.....       | 68.0                               | 65.4 | 63.0 | 60.7 | 58.6 | 56.7 | 54.8 | 53.1 | 51.5 | 50.0 | 48.6 | 47.2 | 45.9 | 44.7 | 43.6 | 42.5 | 41.5 | 40.5 | 39.5 | 38.6 |
| 17.1 grams.....       | 68.4                               | 65.8 | 63.3 | 61.1 | 59.0 | 57.0 | 55.2 | 53.4 | 51.8 | 50.3 | 48.8 | 47.2 | 46.0 | 44.8 | 43.6 | 42.5 | 41.5 | 40.5 | 39.5 | 38.9 |
| 17.2 grams.....       | 68.8                               | 66.1 | 63.7 | 61.4 | 59.3 | 57.3 | 55.5 | 53.7 | 52.1 | 50.6 | 49.1 | 47.8 | 46.5 | 45.3 | 44.1 | 43.0 | 41.9 | 40.9 | 40.0 | 39.1 |
| 17.3 grams.....       | 69.2                               | 66.5 | 64.1 | 61.8 | 59.6 | 57.7 | 55.8 | 54.1 | 52.4 | 50.9 | 49.4 | 48.0 | 46.7 | 45.5 | 44.3 | 43.2 | 42.2 | 41.2 | 40.2 | 39.3 |
| 17.4 grams.....       | 69.6                               | 66.9 | 64.4 | 62.1 | 60.0 | 58.0 | 56.1 | 54.4 | 52.7 | 51.2 | 49.7 | 48.3 | 47.0 | 45.8 | 44.6 | 43.5 | 42.4 | 41.4 | 40.5 | 39.5 |
| 17.5 grams.....       | 70.0                               | 67.3 | 64.8 | 62.5 | 60.3 | 58.3 | 56.4 | 54.7 | 53.0 | 51.5 | 50.0 | 48.6 | 47.3 | 46.0 | 44.9 | 43.7 | 42.7 | 41.7 | 40.7 | 39.8 |
| 17.6 grams.....       | 70.4                               | 67.7 | 65.2 | 62.8 | 60.7 | 58.7 | 56.8 | 55.0 | 53.3 | 51.8 | 50.3 | 48.9 | 47.6 | 46.3 | 45.1 | 44.0 | 42.9 | 41.9 | 40.9 | 40.0 |
| 17.7 grams.....       | 70.8                               | 68.1 | 65.5 | 63.2 | 61.0 | 59.0 | 57.1 | 55.3 | 53.6 | 52.0 | 50.6 | 49.2 | 47.8 | 46.6 | 45.4 | 44.2 | 43.2 | 42.2 | 41.2 | 40.2 |
| 17.8 grams.....       | 71.2                               | 68.5 | 65.9 | 63.6 | 61.4 | 59.4 | 57.4 | 55.6 | 53.9 | 52.3 | 50.8 | 49.4 | 48.1 | 46.8 | 45.6 | 44.5 | 43.4 | 42.4 | 41.4 | 40.4 |
| 17.9 grams.....       | 71.6                               | 68.8 | 66.3 | 63.9 | 61.7 | 59.7 | 57.7 | 55.9 | 54.2 | 52.6 | 51.1 | 49.7 | 48.4 | 47.1 | 45.9 | 44.7 | 43.6 | 42.6 | 41.6 | 40.7 |
| 18.0 grams.....       | 72.0                               | 69.2 | 66.7 | 64.3 | 62.1 | 60.0 | 58.1 | 56.2 | 54.5 | 52.9 | 51.4 | 50.0 | 48.6 | 47.4 | 46.1 | 45.0 | 43.9 | 42.8 | 41.9 | 40.9 |
| 18.1 grams.....       | 72.4                               | 69.6 | 67.0 | 64.6 | 62.4 | 60.3 | 58.4 | 56.6 | 54.8 | 53.2 | 51.7 | 50.3 | 48.9 | 47.6 | 46.4 | 45.2 | 44.1 | 43.1 | 42.1 | 41.1 |
| 18.2 grams.....       | 72.8                               | 70.0 | 67.4 | 65.0 | 62.7 | 60.6 | 58.7 | 56.9 | 55.1 | 53.5 | 52.0 | 50.5 | 49.2 | 47.9 | 46.7 | 45.5 | 44.4 | 43.4 | 42.3 | 41.4 |
| 18.3 grams.....       | 73.2                               | 70.4 | 67.8 | 65.3 | 63.1 | 61.0 | 59.0 | 57.2 | 55.4 | 53.8 | 52.3 | 50.8 | 49.4 | 48.1 | 46.9 | 45.7 | 44.6 | 43.6 | 42.5 | 41.6 |
| 18.4 grams.....       | 73.6                               | 70.8 | 68.1 | 65.7 | 63.4 | 61.3 | 59.3 | 57.5 | 55.7 | 54.1 | 52.6 | 51.1 | 49.7 | 48.4 | 47.2 | 46.0 | 44.9 | 43.8 | 42.8 | 41.8 |
| 18.5 grams.....       | 74.0                               | 71.1 | 68.5 | 66.1 | 63.8 | 61.7 | 59.7 | 57.8 | 56.1 | 54.4 | 52.8 | 51.4 | 50.0 | 48.7 | 47.4 | 46.2 | 45.1 | 44.0 | 43.0 | 42.0 |
| 18.6 grams.....       | 74.4                               | 71.5 | 68.9 | 66.4 | 64.1 | 62.0 | 60.0 | 58.1 | 56.4 | 54.7 | 53.1 | 51.7 | 50.3 | 48.9 | 47.7 | 46.5 | 45.4 | 44.3 | 43.3 | 42.3 |
| 18.7 grams.....       | 74.8                               | 71.9 | 69.2 | 66.8 | 64.5 | 62.3 | 60.3 | 58.4 | 56.7 | 55.0 | 53.4 | 51.9 | 50.5 | 49.2 | 47.9 | 46.7 | 45.6 | 44.5 | 43.5 | 42.5 |
| 18.8 grams.....       | 75.2                               | 72.3 | 69.6 | 67.1 | 64.8 | 62.7 | 60.6 | 58.7 | 57.0 | 55.3 | 53.7 | 52.2 | 50.8 | 49.5 | 48.2 | 47.0 | 45.8 | 44.8 | 43.7 | 42.7 |
| 18.9 grams.....       | 75.6                               | 72.7 | 70.0 | 67.5 | 65.2 | 63.0 | 61.0 | 59.1 | 57.3 | 55.6 | 54.0 | 52.5 | 51.1 | 49.7 | 48.5 | 47.2 | 46.1 | 45.0 | 43.9 | 42.9 |
| 19.0 grams.....       | 76.0                               | 73.1 | 70.4 | 67.9 | 65.5 | 63.3 | 61.3 | 59.4 | 57.6 | 55.9 | 54.3 | 52.8 | 51.3 | 50.0 | 48.7 | 47.5 | 46.3 | 45.2 | 44.2 | 43.2 |
| 19.1 grams.....       | 76.4                               | 73.5 | 70.7 | 68.2 | 65.9 | 63.7 | 61.6 | 59.7 | 57.9 | 56.2 | 54.5 | 53.0 | 51.6 | 50.3 | 49.0 | 47.7 | 46.6 | 45.5 | 44.4 | 43.4 |
| 19.2 grams.....       | 76.8                               | 73.8 | 71.1 | 68.6 | 66.2 | 64.0 | 61.9 | 60.0 | 58.2 | 56.5 | 54.8 | 53.3 | 51.9 | 50.5 | 49.2 | 48.0 | 46.8 | 45.7 | 44.6 | 43.6 |
| 19.3 grams.....       | 77.2                               | 74.2 | 71.5 | 68.9 | 66.5 | 64.3 | 62.2 | 60.3 | 58.5 | 56.8 | 55.1 | 53.6 | 52.2 | 50.8 | 49.5 | 48.2 | 47.1 | 45.9 | 44.9 | 43.9 |
| 19.4 grams.....       | 77.6                               | 74.6 | 71.8 | 69.3 | 66.9 | 64.6 | 62.5 | 60.5 | 58.7 | 57.0 | 55.3 | 53.7 | 52.3 | 50.9 | 49.6 | 48.3 | 47.2 | 46.1 | 45.0 | 44.1 |
| 19.5 grams.....       | 78.0                               | 75.0 | 72.2 | 69.6 | 67.2 | 65.0 | 62.9 | 60.9 | 59.1 | 57.3 | 55.7 | 54.2 | 52.7 | 51.3 | 50.0 | 48.7 | 47.6 | 46.4 | 45.3 | 44.3 |
| 19.6 grams.....       | 78.4                               | 75.4 | 72.6 | 70.0 | 67.6 | 65.3 | 63.2 | 61.2 | 59.4 | 57.6 | 56.0 | 54.4 | 53.0 | 51.6 | 50.2 | 48.9 | 47.8 | 46.7 | 45.6 | 44.5 |
| 19.7 grams.....       | 78.8                               | 75.8 | 73.0 | 70.3 | 67.9 | 65.6 | 63.5 | 61.5 | 59.7 | 57.9 | 56.3 | 54.7 | 53.2 | 51.8 | 50.5 | 49.2 | 48.0 | 46.9 | 45.8 | 44.8 |
| 19.8 grams.....       | 79.2                               | 76.1 | 73.3 | 70.6 | 68.2 | 65.9 | 63.8 | 61.8 | 60.0 | 58.2 | 56.6 | 55.0 | 53.5 | 52.1 | 50.8 | 49.5 | 48.3 | 47.2 | 46.1 | 45.0 |
| 19.9 grams.....       | 79.6                               | 76.5 | 73.7 | 71.0 | 68.6 | 66.3 | 64.2 | 62.2 | 60.3 | 58.5 | 56.8 | 55.3 | 53.8 | 52.4 | 51.0 | 49.7 | 48.5 | 47.4 | 46.3 | 45.2 |
| 20.0 grams.....       | 80.0                               | 76.9 | 74.1 | 71.4 | 69.0 | 66.7 | 64.5 | 62.5 | 60.6 | 58.8 | 57.1 | 55.5 | 54.0 | 52.6 | 51.3 | 50.0 | 48.8 | 47.6 | 46.5 | 45.4 |



TABLE I.—*Equivalent percentage of a sample of wheat, etc., when the weights of the sample analyzed and of the mechanical separation are given—Continued.*

| Weight of separation | Weight of sample analyzed (grams). |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
|----------------------|------------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
|                      | 45                                 | 46   | 47   | 48   | 49   | 50   | 51   | 52   | 53   | 54   | 55   | 56   | 57   | 58   | 59   | 60   | 61   | 62   | 63   |
| 15.1 grams           | 33.5                               | 32.8 | 32.1 | 31.4 | 30.8 | 30.2 | 29.6 | 29.0 | 28.5 | 28.0 | 27.4 | 27.0 | 26.5 | 26.0 | 25.6 | 25.2 | 24.7 | 24.3 | 24.0 |
| 15.2 grams           | 33.8                               | 33.0 | 32.3 | 31.7 | 31.0 | 30.4 | 29.8 | 29.2 | 28.7 | 28.1 | 27.6 | 27.1 | 26.7 | 26.2 | 25.8 | 25.3 | 24.9 | 24.5 | 24.1 |
| 15.3 grams           | 34.0                               | 33.3 | 32.5 | 31.9 | 31.2 | 30.6 | 30.0 | 29.4 | 28.9 | 28.3 | 27.8 | 27.3 | 26.8 | 26.4 | 25.9 | 25.5 | 25.1 | 24.7 | 24.3 |
| 15.4 grams           | 34.2                               | 33.5 | 32.8 | 32.1 | 31.4 | 30.8 | 30.2 | 29.6 | 29.0 | 28.5 | 28.0 | 27.5 | 27.0 | 26.5 | 26.1 | 25.7 | 25.2 | 24.8 | 24.4 |
| 15.5 grams           | 34.4                               | 33.7 | 33.0 | 32.3 | 31.6 | 31.0 | 30.4 | 29.8 | 29.2 | 28.7 | 28.2 | 27.7 | 27.2 | 26.7 | 26.3 | 25.8 | 25.4 | 25.0 | 24.6 |
| 15.6 grams           | 34.7                               | 33.9 | 33.2 | 32.5 | 31.8 | 31.2 | 30.6 | 30.0 | 29.4 | 28.9 | 28.4 | 27.8 | 27.4 | 26.9 | 26.4 | 26.0 | 25.6 | 25.2 | 24.8 |
| 15.7 grams           | 34.9                               | 34.1 | 33.4 | 32.7 | 32.0 | 31.4 | 30.8 | 30.2 | 29.6 | 29.1 | 28.5 | 28.0 | 27.5 | 27.1 | 26.6 | 26.2 | 25.7 | 25.3 | 24.9 |
| 15.8 grams           | 35.1                               | 34.3 | 33.6 | 32.9 | 32.2 | 31.6 | 31.0 | 30.4 | 29.8 | 29.2 | 28.7 | 28.2 | 27.7 | 27.2 | 26.8 | 26.3 | 25.9 | 25.5 | 25.1 |
| 15.9 grams           | 35.3                               | 34.5 | 33.8 | 33.1 | 32.4 | 31.8 | 31.2 | 30.6 | 30.0 | 29.4 | 28.9 | 28.4 | 27.9 | 27.4 | 26.9 | 26.5 | 26.1 | 25.7 | 25.3 |
| 16.0 grams           | 35.5                               | 34.8 | 34.0 | 33.3 | 32.6 | 32.0 | 31.4 | 30.8 | 30.2 | 29.6 | 29.1 | 28.6 | 28.1 | 27.6 | 27.1 | 26.7 | 26.2 | 25.8 | 25.4 |
| 16.1 grams           | 35.8                               | 35.0 | 34.2 | 33.5 | 32.8 | 32.2 | 31.6 | 31.0 | 30.4 | 29.8 | 29.3 | 28.7 | 28.2 | 27.7 | 27.3 | 26.8 | 26.4 | 26.0 | 25.5 |
| 16.2 grams           | 36.0                               | 35.2 | 34.5 | 33.7 | 33.1 | 32.4 | 31.8 | 31.1 | 30.6 | 30.0 | 29.4 | 28.9 | 28.4 | 27.9 | 27.4 | 27.0 | 26.5 | 26.1 | 25.7 |
| 16.3 grams           | 36.2                               | 35.4 | 34.7 | 33.9 | 33.3 | 32.6 | 32.0 | 31.3 | 30.7 | 30.2 | 29.6 | 29.1 | 28.6 | 28.1 | 27.6 | 27.2 | 26.7 | 26.3 | 25.9 |
| 16.4 grams           | 36.4                               | 35.6 | 34.9 | 34.2 | 33.5 | 32.8 | 32.1 | 31.5 | 30.9 | 30.4 | 29.8 | 29.3 | 28.8 | 28.3 | 27.8 | 27.3 | 26.9 | 26.4 | 26.0 |
| 16.5 grams           | 36.7                               | 35.9 | 35.1 | 34.4 | 33.7 | 33.0 | 32.3 | 31.7 | 31.1 | 30.5 | 30.0 | 29.5 | 28.9 | 28.4 | 28.0 | 27.5 | 27.0 | 26.6 | 26.2 |
| 16.6 grams           | 36.9                               | 36.1 | 35.3 | 34.6 | 33.9 | 33.2 | 32.5 | 31.9 | 31.3 | 30.7 | 30.2 | 29.6 | 29.1 | 28.6 | 28.1 | 27.7 | 27.2 | 26.8 | 26.3 |
| 16.7 grams           | 37.1                               | 36.3 | 35.5 | 34.8 | 34.1 | 33.4 | 32.7 | 32.1 | 31.5 | 30.9 | 30.4 | 29.8 | 29.3 | 28.8 | 28.3 | 27.8 | 27.3 | 26.9 | 26.5 |
| 16.8 grams           | 37.3                               | 36.5 | 35.7 | 35.0 | 34.3 | 33.6 | 32.9 | 32.3 | 31.7 | 31.1 | 30.5 | 30.0 | 29.5 | 29.0 | 28.5 | 28.0 | 27.5 | 27.1 | 26.7 |
| 16.9 grams           | 37.5                               | 36.7 | 35.9 | 35.2 | 34.5 | 33.8 | 33.1 | 32.5 | 31.9 | 31.3 | 30.7 | 30.2 | 29.6 | 29.1 | 28.6 | 28.2 | 27.7 | 27.2 | 26.8 |
| 17.0 grams           | 37.8                               | 36.9 | 36.2 | 35.4 | 34.7 | 34.0 | 33.3 | 32.7 | 32.1 | 31.5 | 30.9 | 30.3 | 29.8 | 29.3 | 28.8 | 28.3 | 27.9 | 27.4 | 27.0 |
| 17.1 grams           | 38.0                               | 37.2 | 36.4 | 35.7 | 35.0 | 34.3 | 33.6 | 32.9 | 32.3 | 31.7 | 31.1 | 30.5 | 30.0 | 29.5 | 29.0 | 28.5 | 28.0 | 27.6 | 27.2 |
| 17.2 grams           | 38.2                               | 37.4 | 36.6 | 35.8 | 35.1 | 34.4 | 33.7 | 33.1 | 32.4 | 31.8 | 31.3 | 30.7 | 30.2 | 29.6 | 29.1 | 28.7 | 28.2 | 27.7 | 27.3 |
| 17.3 grams           | 38.4                               | 37.6 | 36.8 | 36.0 | 35.3 | 34.6 | 33.9 | 33.3 | 32.6 | 32.0 | 31.4 | 30.9 | 30.3 | 29.8 | 29.3 | 28.8 | 28.4 | 27.9 | 27.5 |
| 17.4 grams           | 38.7                               | 37.8 | 37.0 | 36.2 | 35.5 | 34.8 | 34.1 | 33.5 | 32.8 | 32.2 | 31.6 | 31.1 | 30.5 | 30.0 | 29.5 | 29.0 | 28.5 | 28.1 | 27.6 |
| 17.5 grams           | 38.9                               | 38.0 | 37.2 | 36.4 | 35.7 | 35.0 | 34.3 | 33.6 | 33.0 | 32.4 | 31.8 | 31.2 | 30.7 | 30.2 | 29.7 | 29.2 | 28.7 | 28.2 | 27.8 |
| 17.6 grams           | 39.1                               | 38.3 | 37.4 | 36.7 | 35.9 | 35.2 | 34.5 | 33.8 | 33.2 | 32.6 | 32.0 | 31.4 | 30.9 | 30.3 | 29.8 | 29.3 | 28.8 | 28.4 | 27.9 |
| 17.7 grams           | 39.3                               | 38.5 | 37.6 | 36.9 | 36.1 | 35.4 | 34.7 | 34.0 | 33.4 | 32.8 | 32.2 | 31.6 | 31.0 | 30.5 | 30.0 | 29.5 | 29.0 | 28.5 | 28.1 |
| 17.8 grams           | 39.5                               | 38.7 | 37.9 | 37.1 | 36.3 | 35.6 | 34.9 | 34.2 | 33.6 | 33.0 | 32.4 | 31.8 | 31.2 | 30.7 | 30.2 | 29.7 | 29.2 | 28.7 | 28.2 |
| 17.9 grams           | 39.8                               | 38.9 | 38.1 | 37.3 | 36.5 | 35.8 | 35.1 | 34.4 | 33.8 | 33.2 | 32.6 | 32.0 | 31.4 | 30.9 | 30.3 | 29.8 | 29.3 | 28.8 | 28.4 |
| 18.0 grams           | 40.0                               | 39.1 | 38.3 | 37.5 | 36.7 | 36.0 | 35.3 | 34.6 | 34.0 | 33.3 | 32.7 | 32.1 | 31.6 | 31.0 | 30.5 | 30.0 | 29.5 | 29.0 | 28.6 |
| 18.1 grams           | 40.2                               | 39.3 | 38.5 | 37.7 | 36.9 | 36.2 | 35.5 | 34.8 | 34.1 | 33.5 | 32.9 | 32.3 | 31.7 | 31.2 | 30.7 | 30.2 | 29.7 | 29.2 | 28.7 |
| 18.2 grams           | 40.4                               | 39.6 | 38.7 | 37.9 | 37.1 | 36.4 | 35.7 | 35.0 | 34.3 | 33.7 | 33.1 | 32.5 | 31.9 | 31.4 | 30.8 | 30.3 | 29.8 | 29.3 | 28.8 |
| 18.3 grams           | 40.7                               | 39.8 | 38.9 | 38.1 | 37.3 | 36.6 | 35.9 | 35.2 | 34.5 | 33.9 | 33.3 | 32.7 | 32.1 | 31.5 | 31.0 | 30.5 | 30.0 | 29.5 | 29.0 |
| 18.4 grams           | 40.9                               | 40.0 | 39.1 | 38.3 | 37.5 | 36.8 | 36.1 | 35.4 | 34.7 | 34.1 | 33.4 | 32.8 | 32.3 | 31.7 | 31.2 | 30.7 | 30.2 | 29.7 | 29.2 |
| 18.5 grams           | 41.1                               | 40.2 | 39.4 | 38.5 | 37.7 | 37.0 | 36.3 | 35.6 | 34.9 | 34.2 | 33.6 | 33.0 | 32.4 | 31.9 | 31.3 | 30.8 | 30.3 | 29.8 | 29.3 |
| 18.6 grams           | 41.3                               | 40.4 | 39.6 | 38.7 | 37.9 | 37.2 | 36.5 | 35.8 | 35.1 | 34.4 | 33.8 | 33.2 | 32.6 | 32.1 | 31.5 | 31.0 | 30.5 | 30.0 | 29.5 |
| 18.7 grams           | 41.5                               | 40.6 | 39.8 | 38.9 | 38.2 | 37.4 | 36.7 | 36.0 | 35.3 | 34.6 | 34.0 | 33.4 | 32.8 | 32.2 | 31.7 | 31.2 | 30.6 | 30.2 | 29.7 |
| 18.8 grams           | 41.8                               | 40.9 | 40.0 | 39.2 | 38.4 | 37.6 | 36.9 | 36.1 | 35.5 | 34.8 | 34.2 | 33.6 | 33.0 | 32.4 | 31.9 | 31.3 | 30.8 | 30.3 | 29.8 |
| 18.9 grams           | 42.0                               | 41.1 | 40.2 | 39.4 | 38.6 | 37.8 | 37.0 | 36.3 | 35.7 | 35.0 | 34.4 | 33.7 | 33.1 | 32.6 | 32.0 | 31.5 | 31.0 | 30.5 | 30.0 |
| 19.0 grams           | 42.2                               | 41.3 | 40.4 | 39.6 | 38.8 | 38.0 | 37.2 | 36.5 | 35.8 | 35.2 | 34.5 | 33.9 | 33.3 | 32.7 | 32.1 | 31.7 | 31.1 | 30.6 | 30.2 |
| 19.1 grams           | 42.4                               | 41.5 | 40.6 | 39.8 | 39.0 | 38.2 | 37.4 | 36.7 | 36.0 | 35.4 | 34.7 | 34.1 | 33.5 | 32.9 | 32.4 | 31.8 | 31.3 | 30.8 | 30.3 |
| 19.2 grams           | 42.7                               | 41.7 | 40.8 | 40.0 | 39.2 | 38.4 | 37.6 | 36.9 | 36.2 | 35.5 | 34.9 | 34.3 | 33.7 | 33.1 | 32.5 | 32.0 | 31.5 | 31.0 | 30.5 |
| 19.3 grams           | 42.9                               | 41.9 | 41.1 | 40.2 | 39.4 | 38.6 | 37.8 | 37.1 | 36.4 | 35.7 | 35.1 | 34.5 | 33.8 | 33.2 | 32.7 | 32.1 | 31.6 | 31.1 | 30.6 |
| 19.4 grams           | 43.1                               | 42.2 | 41.3 | 40.4 | 39.6 | 38.8 | 38.0 | 37.3 | 36.6 | 35.9 | 35.3 | 34.7 | 34.1 | 33.5 | 32.9 | 32.3 | 31.8 | 31.3 | 30.8 |
| 19.5 grams           | 43.3                               | 42.4 | 41.5 | 40.6 | 39.8 | 39.0 | 38.2 | 37.5 | 36.8 | 36.1 | 35.4 | 34.8 | 34.2 | 33.6 | 33.0 | 32.5 | 32.0 | 31.4 | 30.9 |
| 19.6 grams           | 43.5                               | 42.6 | 41.7 | 40.8 | 40.0 | 39.2 | 38.4 | 37.7 | 37.0 | 36.3 | 35.6 | 35.0 | 34.4 | 33.8 | 33.2 | 32.7 | 32.1 | 31.6 | 31.1 |
| 19.7 grams           | 43.8                               | 42.8 | 41.9 | 41.0 | 40.2 | 39.4 | 38.6 | 37.9 | 37.2 | 36.5 | 35.8 | 35.2 | 34.6 | 34.0 | 33.4 | 32.8 | 32.3 | 31.8 | 31.3 |
| 19.8 grams           | 44.0                               | 43.0 | 42.1 | 41.2 | 40.4 | 39.6 | 38.8 | 38.1 | 37.3 | 36.7 | 36.0 | 35.3 | 34.7 | 34.1 | 33.5 | 33.0 | 32.4 | 31.9 | 31.4 |
| 19.9 grams           | 44.2                               | 43.3 | 42.3 | 41.4 | 40.6 | 39.8 | 39.0 | 38.3 | 37.5 | 36.8 | 36.2 | 35.5 | 34.9 | 34.3 | 33.7 | 33.2 | 32.6 | 32.1 | 31.6 |
| 20.0 grams           | 44.4                               | 43.5 | 42.5 | 41.6 | 40.8 | 40.0 | 39.2 | 38.5 | 37.7 | 37.0 | 36.4 | 35.7 | 35.1 | 34.5 | 33.9 | 33.3 | 32.8 | 32.2 | 31.7 |



TABLE II.—*Equivalent percentage of a sample of corn, etc., when the weights of the sample analyzed and of the mechanical separation are given.*

| Weight of separation. | Weight of sample analyzed (grams). |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |  |
|-----------------------|------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|--|
|                       | 240                                | 241 | 242 | 243 | 244 | 245 | 246 | 247 | 248 | 249 | 250 | 251 | 252 | 253 | 254 | 255 | 256 | 257 | 258 | 259 | 260 |  |
| 0.1 gram              | 0                                  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   |  |
| .2 gram               | .1                                 | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  |  |
| .3 gram               | .1                                 | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  |  |
| .4 gram               | .2                                 | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  | .1  |  |
| .5 gram               | .2                                 | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  |  |
| .6 gram               | .2                                 | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  | .2  |  |
| .7 gram               | .3                                 | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  |  |
| .8 gram               | .3                                 | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  |  |
| .9 gram               | .4                                 | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  | .3  |  |
| 1.0 gram              | .4                                 | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  |  |
| 1.1 grams             | .4                                 | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  | .4  |  |
| 1.2 grams             | .5                                 | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  |  |
| 1.3 grams             | .5                                 | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  |  |
| 1.4 grams             | .6                                 | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  | .5  |  |
| 1.5 grams             | .6                                 | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  |  |
| 1.6 grams             | .7                                 | .7  | .7  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  | .6  |  |
| 1.7 grams             | .7                                 | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .6  | .6  | .6  |  |
| 1.8 grams             | .7                                 | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  |  |
| 1.9 grams             | .8                                 | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  | .7  |  |
| 2.0 grams             | .8                                 | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .8  |  |
| 2.1 grams             | .9                                 | .9  | .9  | .9  | .9  | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .8  | .8  |  |
| 2.2 grams             | .9                                 | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .8  | .8  | .8  | .8  |  |
| 2.3 grams             | .9                                 | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .9  |  |
| 2.4 grams             | 1.0                                | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .9  | .9  |  |
| 2.5 grams             | 1.0                                | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |  |
| 2.6 grams             | 1.1                                | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |  |
| 2.7 grams             | 1.1                                | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |  |
| 2.8 grams             | 1.2                                | 1.2 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 |  |
| 2.9 grams             | 1.2                                | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 |  |
| 3.0 grams             | 1.2                                | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.1 | 1.1 |  |
| 3.1 grams             | 1.3                                | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |  |
| 3.2 grams             | 1.3                                | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |  |
| 3.3 grams             | 1.4                                | 1.4 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 |  |
| 3.4 grams             | 1.4                                | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 |  |
| 3.5 grams             | 1.4                                | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.3 | 1.3 | 1.3 |  |
| 3.6 grams             | 1.5                                | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 |  |
| 3.7 grams             | 1.5                                | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 |  |
| 3.8 grams             | 1.6                                | 1.6 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |  |
| 3.9 grams             | 1.6                                | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |  |
| 4.0 grams             | 1.7                                | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 |  |
| 4.1 grams             | 1.7                                | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 |  |
| 4.2 grams             | 1.7                                | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 |  |
| 4.3 grams             | 1.8                                | 1.8 | 1.8 | 1.8 | 1.8 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.6 |  |
| 4.4 grams             | 1.8                                | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 |  |
| 4.5 grams             | 1.9                                | 1.9 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 |  |
| 4.6 grams             | 1.9                                | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 |  |
| 4.7 grams             | 1.9                                | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 |  |
| 4.8 grams             | 2.0                                | 2.0 | 2.0 | 2.0 | 2.0 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.8 | 1.8 |  |
| 4.9 grams             | 2.0                                | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 |  |
| 5.0 grams             | 2.1                                | 2.1 | 2.1 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 |  |

TABLE II.—Equivalent percentage of a sample of corn, etc., when the weights of the sample analyzed and of the mechanical separation are given—Continued.

| Weight of separation. | Weight of sample analyzed (grams). |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|-----------------------|------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|                       | 240                                | 241 | 242 | 243 | 244 | 245 | 246 | 247 | 248 | 249 | 250 | 251 | 252 | 253 | 254 | 255 | 256 | 257 | 258 | 259 |
| 5.1 grams             | 2.1                                | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 5.2 grams             | 2.2                                | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 5.3 grams             | 2.2                                | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.0 | 2.0 |
| 5.4 grams             | 2.2                                | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 |
| 5.5 grams             | 2.3                                | 2.3 | 2.3 | 2.3 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.1 |
| 5.6 grams             | 2.3                                | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.1 |
| 5.7 grams             | 2.4                                | 2.4 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |
| 5.8 grams             | 2.4                                | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.2 | 2.2 | 2.2 |
| 5.9 grams             | 2.4                                | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 |
| 6.0 grams             | 2.5                                | 2.5 | 2.5 | 2.5 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 |
| 6.1 grams             | 2.5                                | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.3 |
| 6.2 grams             | 2.6                                | 2.6 | 2.6 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 |
| 6.3 grams             | 2.6                                | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.4 | 2.4 | 2.4 |
| 6.4 grams             | 2.7                                | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| 6.5 grams             | 2.7                                | 2.7 | 2.7 | 2.7 | 2.7 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| 6.6 grams             | 2.7                                | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.5 | 2.5 |
| 6.7 grams             | 2.8                                | 2.8 | 2.8 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 |
| 6.8 grams             | 2.8                                | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.6 | 2.6 | 2.6 | 2.6 |
| 6.9 grams             | 2.9                                | 2.9 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.6 |
| 7.0 grams             | 2.9                                | 2.9 | 2.9 | 2.9 | 2.9 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 |
| 7.1 grams             | 2.9                                | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.7 | 2.7 |
| 7.2 grams             | 3.0                                | 3.0 | 3.0 | 3.0 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 |
| 7.3 grams             | 3.0                                | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.8 | 2.8 | 2.8 | 2.8 |
| 7.4 grams             | 3.1                                | 3.1 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.8 | 2.8 |
| 7.5 grams             | 3.1                                | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 |
| 7.6 grams             | 3.2                                | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 2.9 | 2.9 | 2.9 | 2.9 |
| 7.7 grams             | 3.2                                | 3.2 | 3.2 | 3.2 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 7.8 grams             | 3.2                                | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 7.9 grams             | 3.3                                | 3.3 | 3.3 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.0 |
| 8.0 grams             | 3.3                                | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 |
| 8.1 grams             | 3.4                                | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.1 | 3.1 | 3.1 |
| 8.2 grams             | 3.4                                | 3.4 | 3.4 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.1 |
| 8.3 grams             | 3.4                                | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 |
| 8.4 grams             | 3.5                                | 3.5 | 3.5 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.2 | 3.2 |
| 8.5 grams             | 3.5                                | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 |
| 8.6 grams             | 3.6                                | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.3 | 3.3 |
| 8.7 grams             | 3.6                                | 3.6 | 3.6 | 3.6 | 3.6 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.3 |
| 8.8 grams             | 3.7                                | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 |
| 8.9 grams             | 3.7                                | 3.7 | 3.7 | 3.7 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.4 | 3.4 |
| 9.0 grams             | 3.7                                | 3.7 | 3.7 | 3.7 | 3.7 | 3.7 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 |
| 9.1 grams             | 3.8                                | 3.8 | 3.8 | 3.7 | 3.7 | 3.7 | 3.7 | 3.7 | 3.7 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.5 | 3.5 | 3.5 | 3.5 |
| 9.2 grams             | 3.8                                | 3.8 | 3.8 | 3.8 | 3.8 | 3.7 | 3.7 | 3.7 | 3.7 | 3.7 | 3.7 | 3.7 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.5 |
| 9.3 grams             | 3.9                                | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.7 | 3.7 | 3.7 | 3.7 | 3.7 | 3.7 | 3.7 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 |
| 9.4 grams             | 3.9                                | 3.9 | 3.9 | 3.9 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.7 | 3.7 | 3.7 | 3.7 | 3.6 | 3.6 | 3.6 | 3.6 |
| 9.5 grams             | 3.9                                | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.7 | 3.7 | 3.7 | 3.7 | 3.7 | 3.7 | 3.6 |
| 9.6 grams             | 4.0                                | 4.0 | 4.0 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.7 | 3.7 | 3.7 | 3.7 | 3.7 |
| 9.7 grams             | 4.0                                | 4.0 | 4.0 | 4.0 | 4.0 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.7 |
| 9.8 grams             | 4.1                                | 4.1 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 |
| 9.9 grams             | 4.1                                | 4.1 | 4.1 | 4.1 | 4.1 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.8 | 3.8 | 3.8 |
| 10.0 grams            | 4.2                                | 4.1 | 4.1 | 4.1 | 4.1 | 4.1 | 4.1 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.8 |

TABLE II.—*Equivalent percentage of a sample of corn, etc., when the weights of the sample analyzed and of the mechanical separation are given—Continued.*

| Weight of separation. | Weight of sample analyzed (grams). |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |  |
|-----------------------|------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|--|
|                       | 240                                | 241 | 242 | 243 | 244 | 245 | 246 | 247 | 248 | 249 | 250 | 251 | 252 | 253 | 254 | 255 | 256 | 257 | 258 | 259 | 260 |  |
| 10.1 grams            | 4.2                                | 4.2 | 4.2 | 4.1 | 4.1 | 4.1 | 4.1 | 4.1 | 4.1 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 |  |
| 10.2 grams            | 4.2                                | 4.2 | 4.2 | 4.2 | 4.2 | 4.2 | 4.1 | 4.1 | 4.1 | 4.1 | 4.1 | 4.1 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 3.9 | 3.9 | 3.9 |  |
| 10.3 grams            | 4.3                                | 4.3 | 4.2 | 4.2 | 4.2 | 4.2 | 4.2 | 4.2 | 4.1 | 4.1 | 4.1 | 4.1 | 4.1 | 4.1 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |  |
| 10.4 grams            | 4.3                                | 4.3 | 4.3 | 4.3 | 4.3 | 4.2 | 4.2 | 4.2 | 4.2 | 4.2 | 4.2 | 4.1 | 4.1 | 4.1 | 4.1 | 4.1 | 4.1 | 4.0 | 4.0 | 4.0 | 4.0 |  |
| 10.5 grams            | 4.4                                | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.2 | 4.2 | 4.2 | 4.2 | 4.2 | 4.1 | 4.1 | 4.1 | 4.1 | 4.1 | 4.1 | 4.1 | 4.0 | 4.0 |  |
| 10.6 grams            | 4.4                                | 4.4 | 4.4 | 4.4 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.2 | 4.2 | 4.2 | 4.2 | 4.2 | 4.2 | 4.1 | 4.1 | 4.1 | 4.1 | 4.1 | 4.1 |  |
| 10.7 grams            | 4.4                                | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.2 | 4.2 | 4.2 | 4.2 | 4.2 | 4.2 | 4.1 | 4.1 | 4.1 |  |
| 10.8 grams            | 4.5                                | 4.5 | 4.5 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.2 | 4.2 | 4.2 | 4.2 | 4.2 | 4.2 | 4.1 |  |
| 10.9 grams            | 4.5                                | 4.5 | 4.5 | 4.5 | 4.5 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.2 | 4.2 | 4.2 | 4.2 | 4.2 |  |
| 11.0 grams            | 4.6                                | 4.6 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.2 | 4.2 |  |
| 11.1 grams            | 4.6                                | 4.6 | 4.6 | 4.6 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 |  |
| 11.2 grams            | 4.7                                | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 4.3 | 4.3 | 4.3 | 4.3 |  |
| 11.3 grams            | 4.7                                | 4.7 | 4.7 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 4.3 |  |
| 11.4 grams            | 4.7                                | 4.7 | 4.7 | 4.7 | 4.7 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 |  |
| 11.5 grams            | 4.8                                | 4.8 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.4 | 4.4 | 4.4 |  |
| 11.6 grams            | 4.8                                | 4.8 | 4.8 | 4.8 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 |  |
| 11.7 grams            | 4.9                                | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.5 | 4.5 | 4.5 | 4.5 |  |
| 11.8 grams            | 4.9                                | 4.9 | 4.9 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.7 | 4.7 | 4.7 | 4.7 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.5 | 4.5 | 4.5 |  |
| 11.9 grams            | 4.9                                | 4.9 | 4.9 | 4.9 | 4.9 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 |  |
| 12.0 grams            | 5.0                                | 5.0 | 4.9 | 4.9 | 4.9 | 4.9 | 4.9 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.6 | 4.6 | 4.6 |  |
| 12.1 grams            | 5.0                                | 5.0 | 5.0 | 5.0 | 4.9 | 4.9 | 4.9 | 4.9 | 4.9 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.6 |  |
| 12.2 grams            | 5.1                                | 5.1 | 5.0 | 5.0 | 5.0 | 5.0 | 4.9 | 4.9 | 4.9 | 4.9 | 4.9 | 4.9 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.7 | 4.7 | 4.7 | 4.7 |  |
| 12.3 grams            | 5.1                                | 5.1 | 5.1 | 5.1 | 5.0 | 5.0 | 5.0 | 5.0 | 4.9 | 4.9 | 4.9 | 4.9 | 4.9 | 4.9 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.7 | 4.7 |  |
| 12.4 grams            | 5.2                                | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.9 | 4.9 | 4.9 | 4.9 | 4.9 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 |  |
| 12.5 grams            | 5.2                                | 5.2 | 5.2 | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.9 | 4.9 | 4.9 | 4.9 | 4.9 | 4.8 | 4.8 | 4.8 |  |
| 12.6 grams            | 5.2                                | 5.2 | 5.2 | 5.2 | 5.2 | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.9 | 4.9 | 4.9 | 4.9 | 4.9 | 4.8 |  |
| 12.7 grams            | 5.3                                | 5.3 | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.9 | 4.9 | 4.9 | 4.9 |  |
| 12.8 grams            | 5.3                                | 5.3 | 5.3 | 5.3 | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 | 5.1 | 5.1 | 5.1 | 5.1 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.9 | 4.9 |  |
| 12.9 grams            | 5.4                                | 5.3 | 5.3 | 5.3 | 5.3 | 5.3 | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |  |
| 13.0 grams            | 5.4                                | 5.4 | 5.4 | 5.3 | 5.3 | 5.3 | 5.3 | 5.3 | 5.3 | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 | 5.1 | 5.1 | 5.1 | 5.0 | 5.0 | 5.0 | 5.0 |  |
| 13.1 grams            | 5.4                                | 5.4 | 5.4 | 5.4 | 5.4 | 5.3 | 5.3 | 5.3 | 5.3 | 5.3 | 5.2 | 5.2 | 5.2 | 5.2 | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 | 5.0 | 5.0 |  |
| 13.2 grams            | 5.5                                | 5.5 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.3 | 5.3 | 5.3 | 5.3 | 5.3 | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 | 5.1 | 5.1 | 5.1 | 5.1 |  |
| 13.3 grams            | 5.5                                | 5.5 | 5.5 | 5.5 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.3 | 5.3 | 5.3 | 5.3 | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 | 5.1 | 5.1 | 5.1 |  |
| 13.4 grams            | 5.6                                | 5.6 | 5.5 | 5.5 | 5.5 | 5.5 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.3 | 5.3 | 5.3 | 5.3 | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 | 5.1 |  |
| 13.5 grams            | 5.6                                | 5.6 | 5.6 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.3 | 5.3 | 5.3 | 5.3 | 5.2 | 5.2 | 5.2 | 5.2 |  |
| 13.6 grams            | 5.7                                | 5.6 | 5.6 | 5.6 | 5.6 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.4 | 5.4 | 5.4 | 5.4 | 5.3 | 5.3 | 5.3 | 5.3 | 5.3 | 5.2 | 5.2 |  |
| 13.7 grams            | 5.7                                | 5.7 | 5.7 | 5.6 | 5.6 | 5.6 | 5.6 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.3 | 5.3 | 5.3 | 5.3 |  |
| 13.8 grams            | 5.7                                | 5.7 | 5.7 | 5.7 | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 | 5.5 | 5.5 | 5.5 | 5.5 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.3 | 5.3 | 5.3 |  |
| 13.9 grams            | 5.8                                | 5.8 | 5.7 | 5.7 | 5.7 | 5.7 | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 | 5.5 | 5.5 | 5.5 | 5.5 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.3 |  |
| 14.0 grams            | 5.8                                | 5.8 | 5.8 | 5.8 | 5.7 | 5.7 | 5.7 | 5.7 | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 | 5.5 | 5.5 | 5.5 | 5.5 | 5.4 | 5.4 | 5.4 | 5.4 |  |
| 14.1 grams            | 5.9                                | 5.8 | 5.8 | 5.8 | 5.8 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.6 | 5.6 | 5.6 | 5.6 | 5.5 | 5.5 | 5.5 | 5.5 | 5.4 | 5.4 | 5.4 |  |
| 14.2 grams            | 5.9                                | 5.9 | 5.9 | 5.8 | 5.8 | 5.8 | 5.8 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.6 | 5.6 | 5.6 | 5.6 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 |  |
| 14.3 grams            | 5.9                                | 5.9 | 5.9 | 5.9 | 5.9 | 5.8 | 5.8 | 5.8 | 5.8 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.6 | 5.6 | 5.6 | 5.6 | 5.5 | 5.5 | 5.5 |  |
| 14.4 grams            | 6.0                                | 6.0 | 5.9 | 5.9 | 5.9 | 5.9 | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 | 5.7 | 5.7 | 5.7 | 5.7 | 5.6 | 5.6 | 5.6 | 5.5 | 5.5 | 5.5 |  |
| 14.5 grams            | 6.0                                | 6.0 | 6.0 | 6.0 | 5.9 | 5.9 | 5.9 | 5.9 | 5.8 | 5.8 | 5.8 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.6 | 5.6 | 5.6 | 5.6 |  |
| 14.6 grams            | 6.1                                | 6.0 | 6.0 | 6.0 | 6.0 | 5.9 | 5.9 | 5.9 | 5.9 | 5.9 | 5.8 | 5.8 | 5.8 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.6 | 5.6 | 5.6 |  |
| 14.7 grams            | 6.1                                | 6.1 | 6.1 | 6.1 | 6.0 | 6.0 | 6.0 | 5.9 | 5.9 | 5.9 | 5.9 | 5.9 | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 | 5.7 | 5.7 | 5.7 | 5.6 |  |
| 14.8 grams            | 6.2                                | 6.1 | 6.1 | 6.1 | 6.1 | 6.0 | 6.0 | 6.0 | 6.0 | 5.9 | 5.9 | 5.9 | 5.9 | 5.8 | 5.8 | 5.8 | 5.8 | 5.7 | 5.7 | 5.7 | 5.7 |  |
| 14.9 grams            | 6.2                                | 6.2 | 6.1 | 6.1 | 6.1 | 6.1 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 5.9 | 5.9 | 5.9 | 5.9 | 5.8 | 5.8 | 5.8 | 5.8 | 5.7 | 5.7 |  |
| 15.0 grams            | 6.2                                | 6.2 | 6.2 | 6.2 | 6.1 | 6.1 | 6.1 | 6.1 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 5.9 | 5.9 | 5.9 | 5.9 | 5.8 | 5.8 | 5.8 | 5.8 |  |



TABLE II.—*Equivalent percentage of a sample of corn, etc., when the weights of the sample analyzed and of the mechanical separation are given—Continued.*

| Weight of separation. | Weight of sample analyzed (grams). |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|-----------------------|------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|                       | 240                                | 241 | 242 | 243 | 244 | 245 | 246 | 247 | 248 | 249 | 250 | 251 | 252 | 253 | 254 | 255 | 256 | 257 | 258 | 259 | 260 |
| 15.1 grams            | 6.3                                | 6.3 | 6.2 | 6.2 | 6.2 | 6.2 | 6.1 | 6.1 | 6.1 | 6.1 | 6.0 | 6.0 | 6.0 | 6.0 | 5.9 | 5.9 | 5.9 | 5.9 | 5.8 | 5.8 | 5.8 |
| 15.2 grams            | 6.3                                | 6.3 | 6.3 | 6.2 | 6.2 | 6.2 | 6.2 | 6.1 | 6.1 | 6.1 | 6.1 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 5.9 | 5.9 | 5.9 | 5.9 | 5.8 |
| 15.3 grams            | 6.4                                | 6.3 | 6.3 | 6.3 | 6.3 | 6.2 | 6.2 | 6.2 | 6.2 | 6.1 | 6.1 | 6.1 | 6.1 | 6.0 | 6.0 | 6.0 | 6.0 | 5.9 | 5.9 | 5.9 | 5.9 |
| 15.4 grams            | 6.4                                | 6.4 | 6.4 | 6.3 | 6.3 | 6.3 | 6.3 | 6.2 | 6.2 | 6.2 | 6.2 | 6.1 | 6.1 | 6.1 | 6.1 | 6.0 | 6.0 | 6.0 | 6.0 | 5.9 | 5.9 |
| 15.5 grams            | 6.4                                | 6.4 | 6.4 | 6.4 | 6.3 | 6.3 | 6.3 | 6.3 | 6.2 | 6.2 | 6.2 | 6.2 | 6.1 | 6.1 | 6.1 | 6.1 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| 15.6 grams            | 6.5                                | 6.5 | 6.4 | 6.4 | 6.4 | 6.4 | 6.3 | 6.3 | 6.3 | 6.3 | 6.2 | 6.2 | 6.2 | 6.2 | 6.1 | 6.1 | 6.1 | 6.1 | 6.0 | 6.0 | 6.0 |
| 15.7 grams            | 6.5                                | 6.5 | 6.5 | 6.5 | 6.4 | 6.4 | 6.4 | 6.3 | 6.3 | 6.3 | 6.3 | 6.2 | 6.2 | 6.2 | 6.2 | 6.1 | 6.1 | 6.1 | 6.1 | 6.1 | 6.0 |
| 15.8 grams            | 6.6                                | 6.5 | 6.5 | 6.5 | 6.5 | 6.4 | 6.4 | 6.4 | 6.4 | 6.3 | 6.3 | 6.3 | 6.3 | 6.2 | 6.2 | 6.2 | 6.2 | 6.1 | 6.1 | 6.1 | 6.1 |
| 15.9 grams            | 6.6                                | 6.6 | 6.6 | 6.5 | 6.5 | 6.5 | 6.5 | 6.4 | 6.4 | 6.4 | 6.4 | 6.3 | 6.3 | 6.3 | 6.2 | 6.2 | 6.2 | 6.2 | 6.2 | 6.1 | 6.1 |
| 16.0 grams            | 6.7                                | 6.6 | 6.6 | 6.6 | 6.5 | 6.5 | 6.5 | 6.5 | 6.4 | 6.4 | 6.4 | 6.4 | 6.3 | 6.3 | 6.3 | 6.3 | 6.2 | 6.2 | 6.2 | 6.2 | 6.1 |
| 16.1 grams            | 6.7                                | 6.7 | 6.6 | 6.6 | 6.6 | 6.6 | 6.5 | 6.5 | 6.5 | 6.5 | 6.4 | 6.4 | 6.4 | 6.4 | 6.3 | 6.3 | 6.3 | 6.3 | 6.2 | 6.2 | 6.2 |
| 16.2 grams            | 6.7                                | 6.7 | 6.7 | 6.7 | 6.6 | 6.6 | 6.6 | 6.6 | 6.5 | 6.5 | 6.5 | 6.5 | 6.4 | 6.4 | 6.4 | 6.4 | 6.3 | 6.3 | 6.3 | 6.3 | 6.2 |
| 16.3 grams            | 6.8                                | 6.8 | 6.7 | 6.7 | 6.7 | 6.6 | 6.6 | 6.6 | 6.6 | 6.6 | 6.5 | 6.5 | 6.5 | 6.5 | 6.4 | 6.4 | 6.4 | 6.3 | 6.3 | 6.3 | 6.3 |
| 16.4 grams            | 6.8                                | 6.8 | 6.8 | 6.7 | 6.7 | 6.7 | 6.6 | 6.6 | 6.6 | 6.6 | 6.5 | 6.5 | 6.5 | 6.5 | 6.4 | 6.4 | 6.4 | 6.3 | 6.3 | 6.3 | 6.3 |
| 16.5 grams            | 6.9                                | 6.8 | 6.8 | 6.8 | 6.8 | 6.7 | 6.7 | 6.7 | 6.7 | 6.6 | 6.6 | 6.6 | 6.6 | 6.5 | 6.5 | 6.5 | 6.4 | 6.4 | 6.4 | 6.4 | 6.3 |
| 16.6 grams            | 6.9                                | 6.9 | 6.8 | 6.8 | 6.8 | 6.8 | 6.7 | 6.7 | 6.7 | 6.7 | 6.6 | 6.6 | 6.6 | 6.6 | 6.5 | 6.5 | 6.5 | 6.4 | 6.4 | 6.4 | 6.4 |
| 16.7 grams            | 6.9                                | 6.9 | 6.9 | 6.9 | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 | 6.7 | 6.7 | 6.7 | 6.6 | 6.6 | 6.6 | 6.5 | 6.5 | 6.5 | 6.5 | 6.4 | 6.4 |
| 16.8 grams            | 7.0                                | 7.0 | 6.9 | 6.9 | 6.9 | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 | 6.7 | 6.7 | 6.7 | 6.6 | 6.6 | 6.6 | 6.6 | 6.5 | 6.5 | 6.5 | 6.5 |
| 16.9 grams            | 7.0                                | 7.0 | 7.0 | 6.9 | 6.9 | 6.9 | 6.9 | 6.9 | 6.8 | 6.8 | 6.8 | 6.8 | 6.7 | 6.7 | 6.7 | 6.6 | 6.6 | 6.6 | 6.6 | 6.5 | 6.5 |
| 17.0 grams            | 7.1                                | 7.0 | 7.0 | 7.0 | 7.0 | 6.9 | 6.9 | 6.9 | 6.9 | 6.8 | 6.8 | 6.8 | 6.8 | 6.7 | 6.7 | 6.7 | 6.7 | 6.6 | 6.6 | 6.6 | 6.5 |
| 17.1 grams            | 7.1                                | 7.1 | 7.1 | 7.0 | 7.0 | 7.0 | 6.9 | 6.9 | 6.9 | 6.9 | 6.8 | 6.8 | 6.8 | 6.7 | 6.7 | 6.7 | 6.7 | 6.6 | 6.6 | 6.6 | 6.6 |
| 17.2 grams            | 7.2                                | 7.1 | 7.1 | 7.1 | 7.1 | 7.0 | 7.0 | 7.0 | 7.0 | 6.9 | 6.9 | 6.9 | 6.8 | 6.8 | 6.8 | 6.8 | 6.7 | 6.7 | 6.7 | 6.7 | 6.6 |
| 17.3 grams            | 7.2                                | 7.2 | 7.1 | 7.1 | 7.1 | 7.1 | 7.0 | 7.0 | 7.0 | 6.9 | 6.9 | 6.9 | 6.8 | 6.8 | 6.8 | 6.8 | 6.7 | 6.7 | 6.7 | 6.7 | 6.6 |
| 17.4 grams            | 7.2                                | 7.2 | 7.2 | 7.2 | 7.1 | 7.1 | 7.1 | 7.0 | 7.0 | 7.0 | 7.0 | 6.9 | 6.9 | 6.9 | 6.8 | 6.8 | 6.8 | 6.8 | 6.7 | 6.7 | 6.7 |
| 17.5 grams            | 7.3                                | 7.3 | 7.2 | 7.2 | 7.2 | 7.1 | 7.1 | 7.1 | 7.1 | 7.0 | 7.0 | 7.0 | 6.9 | 6.9 | 6.9 | 6.9 | 6.8 | 6.8 | 6.8 | 6.7 | 6.7 |
| 17.6 grams            | 7.3                                | 7.3 | 7.3 | 7.2 | 7.2 | 7.2 | 7.1 | 7.1 | 7.1 | 7.1 | 7.0 | 7.0 | 6.9 | 6.9 | 6.9 | 6.9 | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 |
| 17.7 grams            | 7.4                                | 7.3 | 7.3 | 7.3 | 7.2 | 7.2 | 7.2 | 7.2 | 7.1 | 7.1 | 7.1 | 7.1 | 7.0 | 7.0 | 7.0 | 7.0 | 6.9 | 6.9 | 6.9 | 6.9 | 6.8 |
| 17.8 grams            | 7.4                                | 7.4 | 7.3 | 7.3 | 7.3 | 7.3 | 7.2 | 7.2 | 7.2 | 7.1 | 7.1 | 7.1 | 7.1 | 7.1 | 7.0 | 7.0 | 6.9 | 6.9 | 6.9 | 6.9 | 6.8 |
| 17.9 grams            | 7.4                                | 7.4 | 7.4 | 7.4 | 7.3 | 7.3 | 7.3 | 7.2 | 7.2 | 7.2 | 7.2 | 7.1 | 7.1 | 7.1 | 7.1 | 7.0 | 7.0 | 7.0 | 7.0 | 6.9 | 6.9 |
| 18.0 grams            | 7.5                                | 7.5 | 7.4 | 7.4 | 7.4 | 7.3 | 7.3 | 7.3 | 7.2 | 7.2 | 7.2 | 7.2 | 7.1 | 7.1 | 7.1 | 7.1 | 7.0 | 7.0 | 7.0 | 7.0 | 6.9 |
| 18.1 grams            | 7.5                                | 7.5 | 7.5 | 7.4 | 7.4 | 7.4 | 7.3 | 7.3 | 7.3 | 7.3 | 7.2 | 7.2 | 7.2 | 7.1 | 7.1 | 7.1 | 7.1 | 7.0 | 7.0 | 7.0 | 7.0 |
| 18.2 grams            | 7.6                                | 7.5 | 7.5 | 7.5 | 7.4 | 7.4 | 7.4 | 7.4 | 7.3 | 7.3 | 7.3 | 7.2 | 7.2 | 7.2 | 7.2 | 7.1 | 7.1 | 7.1 | 7.0 | 7.0 | 7.0 |
| 18.3 grams            | 7.6                                | 7.6 | 7.6 | 7.5 | 7.5 | 7.5 | 7.4 | 7.4 | 7.4 | 7.3 | 7.3 | 7.3 | 7.3 | 7.2 | 7.2 | 7.2 | 7.1 | 7.1 | 7.1 | 7.1 | 7.0 |
| 18.4 grams            | 7.7                                | 7.6 | 7.6 | 7.6 | 7.5 | 7.5 | 7.5 | 7.4 | 7.4 | 7.4 | 7.4 | 7.3 | 7.3 | 7.3 | 7.2 | 7.2 | 7.2 | 7.1 | 7.1 | 7.1 | 7.1 |
| 18.5 grams            | 7.7                                | 7.7 | 7.6 | 7.6 | 7.6 | 7.5 | 7.5 | 7.5 | 7.4 | 7.4 | 7.4 | 7.4 | 7.3 | 7.3 | 7.3 | 7.2 | 7.2 | 7.2 | 7.2 | 7.1 | 7.1 |
| 18.6 grams            | 7.7                                | 7.7 | 7.7 | 7.6 | 7.6 | 7.6 | 7.6 | 7.5 | 7.5 | 7.5 | 7.4 | 7.4 | 7.4 | 7.3 | 7.3 | 7.3 | 7.3 | 7.2 | 7.2 | 7.2 | 7.1 |
| 18.7 grams            | 7.8                                | 7.7 | 7.7 | 7.7 | 7.7 | 7.6 | 7.6 | 7.6 | 7.6 | 7.5 | 7.5 | 7.5 | 7.4 | 7.4 | 7.4 | 7.4 | 7.3 | 7.3 | 7.3 | 7.2 | 7.2 |
| 18.8 grams            | 7.8                                | 7.8 | 7.8 | 7.7 | 7.7 | 7.7 | 7.6 | 7.6 | 7.6 | 7.5 | 7.5 | 7.5 | 7.5 | 7.4 | 7.4 | 7.4 | 7.4 | 7.3 | 7.3 | 7.2 | 7.2 |
| 18.9 grams            | 7.9                                | 7.8 | 7.8 | 7.8 | 7.7 | 7.7 | 7.7 | 7.6 | 7.6 | 7.6 | 7.6 | 7.5 | 7.5 | 7.5 | 7.4 | 7.4 | 7.4 | 7.3 | 7.3 | 7.3 | 7.3 |
| 19.0 grams            | 7.9                                | 7.9 | 7.8 | 7.8 | 7.8 | 7.7 | 7.7 | 7.7 | 7.7 | 7.6 | 7.6 | 7.6 | 7.5 | 7.5 | 7.5 | 7.4 | 7.4 | 7.4 | 7.4 | 7.3 | 7.3 |
| 19.1 grams            | 7.9                                | 7.9 | 7.9 | 7.9 | 7.8 | 7.8 | 7.8 | 7.7 | 7.7 | 7.7 | 7.6 | 7.6 | 7.6 | 7.5 | 7.5 | 7.5 | 7.4 | 7.4 | 7.4 | 7.4 | 7.3 |
| 19.2 grams            | 8.0                                | 8.0 | 7.9 | 7.9 | 7.9 | 7.8 | 7.8 | 7.8 | 7.8 | 7.7 | 7.7 | 7.7 | 7.6 | 7.6 | 7.6 | 7.5 | 7.5 | 7.5 | 7.4 | 7.4 | 7.4 |
| 19.3 grams            | 8.0                                | 8.0 | 8.0 | 7.9 | 7.9 | 7.9 | 7.8 | 7.8 | 7.8 | 7.8 | 7.7 | 7.7 | 7.7 | 7.6 | 7.6 | 7.6 | 7.5 | 7.5 | 7.5 | 7.4 | 7.4 |
| 19.4 grams            | 8.1                                | 8.0 | 8.0 | 8.0 | 7.9 | 7.9 | 7.9 | 7.9 | 7.8 | 7.8 | 7.8 | 7.8 | 7.7 | 7.7 | 7.7 | 7.6 | 7.6 | 7.5 | 7.5 | 7.5 | 7.5 |
| 19.5 grams            | 8.1                                | 8.1 | 8.0 | 8.0 | 8.0 | 7.9 | 7.9 | 7.9 | 7.9 | 7.9 | 7.8 | 7.8 | 7.8 | 7.7 | 7.7 | 7.7 | 7.6 | 7.6 | 7.6 | 7.5 | 7.5 |
| 19.6 grams            | 8.2                                | 8.1 | 8.1 | 8.1 | 8.0 | 8.0 | 8.0 | 8.0 | 7.9 | 7.9 | 7.9 | 7.8 | 7.8 | 7.8 | 7.7 | 7.7 | 7.7 | 7.6 | 7.6 | 7.6 | 7.5 |
| 19.7 grams            | 8.2                                | 8.2 | 8.1 | 8.1 | 8.1 | 8.0 | 8.0 | 8.0 | 8.0 | 7.9 | 7.9 | 7.9 | 7.8 | 7.8 | 7.8 | 7.7 | 7.7 | 7.7 | 7.6 | 7.6 | 7.6 |
| 19.8 grams            | 8.2                                | 8.2 | 8.2 | 8.1 | 8.1 | 8.1 | 8.0 | 8.0 | 8.0 | 7.9 | 7.9 | 7.9 | 7.9 | 7.8 | 7.8 | 7.8 | 7.7 | 7.7 | 7.7 | 7.6 | 7.6 |
| 19.9 grams            | 8.3                                | 8.2 | 8.2 | 8.2 | 8.1 | 8.1 | 8.1 | 8.0 | 8.0 | 8.0 | 8.0 | 7.9 | 7.9 | 7.9 | 7.8 | 7.8 | 7.8 | 7.7 | 7.7 | 7.7 | 7.6 |
| 20.0 grams            | 8.3                                | 8.3 | 8.3 | 8.2 | 8.2 | 8.2 | 8.1 | 8.1 | 8.1 | 8.0 | 8.0 | 8.0 | 7.9 | 7.9 | 7.9 | 7.8 | 7.8 | 7.8 | 7.7 | 7.7 | 7.7 |

TABLE II.—*Equivalent percentage of a sample of corn, etc., when the weights of the sample analyzed and of the mechanical separation are given—Continued.*

| Weight of separation. | Weight of sample analyzed (grams). |      |      |      |      |      |      |      |      |      |      |      |     |     |     |     |     |     |     |     |     |
|-----------------------|------------------------------------|------|------|------|------|------|------|------|------|------|------|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|                       | 240                                | 241  | 242  | 243  | 244  | 245  | 246  | 247  | 248  | 249  | 250  | 251  | 252 | 253 | 254 | 255 | 256 | 257 | 258 | 259 | 260 |
| 20.1 grams            | 8.4                                | 8.3  | 8.3  | 8.3  | 8.2  | 8.2  | 8.2  | 8.1  | 8.1  | 8.1  | 8.0  | 8.0  | 8.0 | 7.9 | 7.9 | 7.9 | 7.8 | 7.8 | 7.8 | 7.8 | 7.7 |
| 20.2 grams            | 8.4                                | 8.4  | 8.3  | 8.3  | 8.3  | 8.2  | 8.2  | 8.2  | 8.1  | 8.1  | 8.1  | 8.0  | 8.0 | 8.0 | 7.9 | 7.9 | 7.9 | 7.8 | 7.8 | 7.8 | 7.7 |
| 20.3 grams            | 8.4                                | 8.4  | 8.4  | 8.3  | 8.3  | 8.3  | 8.2  | 8.2  | 8.2  | 8.1  | 8.1  | 8.1  | 8.0 | 8.0 | 8.0 | 8.0 | 7.9 | 7.9 | 7.9 | 7.8 | 7.8 |
| 20.4 grams            | 8.5                                | 8.5  | 8.4  | 8.4  | 8.4  | 8.3  | 8.3  | 8.2  | 8.2  | 8.2  | 8.2  | 8.1  | 8.1 | 8.1 | 8.0 | 8.0 | 8.0 | 7.9 | 7.9 | 7.9 | 7.8 |
| 20.5 grams            | 8.5                                | 8.5  | 8.5  | 8.4  | 8.4  | 8.4  | 8.3  | 8.3  | 8.3  | 8.2  | 8.2  | 8.2  | 8.1 | 8.1 | 8.1 | 8.0 | 8.0 | 8.0 | 7.9 | 7.9 | 7.9 |
| 20.6 grams            | 8.6                                | 8.5  | 8.5  | 8.5  | 8.4  | 8.4  | 8.4  | 8.3  | 8.3  | 8.3  | 8.2  | 8.2  | 8.2 | 8.1 | 8.1 | 8.1 | 8.0 | 8.0 | 8.0 | 7.9 | 7.9 |
| 20.7 grams            | 8.6                                | 8.6  | 8.5  | 8.5  | 8.5  | 8.4  | 8.4  | 8.4  | 8.3  | 8.3  | 8.3  | 8.2  | 8.2 | 8.2 | 8.1 | 8.1 | 8.1 | 8.0 | 8.0 | 8.0 | 8.0 |
| 20.8 grams            | 8.7                                | 8.6  | 8.6  | 8.5  | 8.5  | 8.5  | 8.4  | 8.4  | 8.4  | 8.3  | 8.3  | 8.3  | 8.2 | 8.2 | 8.2 | 8.1 | 8.1 | 8.1 | 8.1 | 8.0 | 8.0 |
| 20.9 grams            | 8.7                                | 8.7  | 8.6  | 8.6  | 8.6  | 8.5  | 8.5  | 8.5  | 8.4  | 8.4  | 8.4  | 8.3  | 8.3 | 8.3 | 8.2 | 8.2 | 8.2 | 8.1 | 8.1 | 8.1 | 8.0 |
| 21.0 grams            | 8.7                                | 8.7  | 8.7  | 8.6  | 8.6  | 8.6  | 8.5  | 8.5  | 8.5  | 8.4  | 8.4  | 8.4  | 8.3 | 8.3 | 8.3 | 8.2 | 8.2 | 8.2 | 8.1 | 8.1 | 8.1 |
| 21.1 grams            | 8.8                                | 8.7  | 8.7  | 8.7  | 8.6  | 8.6  | 8.6  | 8.5  | 8.5  | 8.5  | 8.4  | 8.4  | 8.4 | 8.3 | 8.3 | 8.3 | 8.2 | 8.2 | 8.2 | 8.1 | 8.1 |
| 21.2 grams            | 8.8                                | 8.8  | 8.8  | 8.7  | 8.7  | 8.6  | 8.6  | 8.6  | 8.5  | 8.5  | 8.5  | 8.4  | 8.4 | 8.4 | 8.3 | 8.3 | 8.3 | 8.2 | 8.2 | 8.2 | 8.1 |
| 21.3 grams            | 8.9                                | 8.8  | 8.8  | 8.8  | 8.7  | 8.7  | 8.6  | 8.6  | 8.6  | 8.6  | 8.5  | 8.5  | 8.4 | 8.4 | 8.4 | 8.3 | 8.3 | 8.3 | 8.2 | 8.2 | 8.2 |
| 21.4 grams            | 8.9                                | 8.9  | 8.8  | 8.8  | 8.8  | 8.7  | 8.7  | 8.7  | 8.6  | 8.6  | 8.6  | 8.5  | 8.5 | 8.4 | 8.4 | 8.4 | 8.3 | 8.3 | 8.3 | 8.3 | 8.2 |
| 21.5 grams            | 8.9                                | 8.9  | 8.9  | 8.8  | 8.8  | 8.8  | 8.7  | 8.7  | 8.7  | 8.6  | 8.6  | 8.6  | 8.5 | 8.5 | 8.5 | 8.4 | 8.4 | 8.4 | 8.3 | 8.3 | 8.3 |
| 21.6 grams            | 9.0                                | 9.0  | 8.9  | 8.9  | 8.8  | 8.8  | 8.8  | 8.7  | 8.7  | 8.7  | 8.6  | 8.6  | 8.6 | 8.5 | 8.5 | 8.5 | 8.4 | 8.4 | 8.4 | 8.3 | 8.3 |
| 21.7 grams            | 9.0                                | 9.0  | 9.0  | 8.9  | 8.9  | 8.8  | 8.8  | 8.8  | 8.7  | 8.7  | 8.6  | 8.6  | 8.6 | 8.5 | 8.5 | 8.5 | 8.4 | 8.4 | 8.4 | 8.3 | 8.3 |
| 21.8 grams            | 9.1                                | 9.0  | 9.0  | 9.0  | 8.9  | 8.9  | 8.9  | 8.8  | 8.8  | 8.7  | 8.7  | 8.6  | 8.6 | 8.6 | 8.5 | 8.5 | 8.5 | 8.4 | 8.4 | 8.4 | 8.3 |
| 21.9 grams            | 9.1                                | 9.1  | 9.0  | 9.0  | 9.0  | 8.9  | 8.9  | 8.9  | 8.8  | 8.8  | 8.8  | 8.7  | 8.7 | 8.6 | 8.6 | 8.6 | 8.5 | 8.5 | 8.5 | 8.4 | 8.4 |
| 22.0 grams            | 9.2                                | 9.1  | 9.1  | 9.0  | 9.0  | 9.0  | 8.9  | 8.9  | 8.9  | 8.8  | 8.8  | 8.8  | 8.7 | 8.7 | 8.7 | 8.6 | 8.6 | 8.6 | 8.5 | 8.5 | 8.5 |
| 22.1 grams            | 9.2                                | 9.2  | 9.1  | 9.1  | 9.0  | 9.0  | 9.0  | 8.9  | 8.9  | 8.9  | 8.8  | 8.8  | 8.8 | 8.7 | 8.7 | 8.7 | 8.6 | 8.6 | 8.6 | 8.5 | 8.5 |
| 22.2 grams            | 9.2                                | 9.2  | 9.2  | 9.1  | 9.1  | 9.1  | 9.0  | 9.0  | 8.9  | 8.9  | 8.9  | 8.8  | 8.8 | 8.8 | 8.7 | 8.7 | 8.7 | 8.6 | 8.6 | 8.6 | 8.5 |
| 22.3 grams            | 9.3                                | 9.2  | 9.2  | 9.2  | 9.1  | 9.1  | 9.1  | 9.0  | 9.0  | 8.9  | 8.9  | 8.9  | 8.8 | 8.8 | 8.8 | 8.7 | 8.7 | 8.7 | 8.6 | 8.6 | 8.6 |
| 22.4 grams            | 9.3                                | 9.3  | 9.2  | 9.2  | 9.2  | 9.1  | 9.1  | 9.1  | 9.0  | 9.0  | 9.0  | 8.9  | 8.9 | 8.8 | 8.8 | 8.8 | 8.7 | 8.7 | 8.7 | 8.6 | 8.6 |
| 22.5 grams            | 9.4                                | 9.3  | 9.3  | 9.2  | 9.2  | 9.2  | 9.1  | 9.1  | 9.1  | 9.0  | 9.0  | 9.0  | 8.9 | 8.9 | 8.8 | 8.8 | 8.8 | 8.7 | 8.7 | 8.7 | 8.6 |
| 22.6 grams            | 9.4                                | 9.4  | 9.3  | 9.3  | 9.3  | 9.2  | 9.2  | 9.1  | 9.1  | 9.1  | 9.0  | 9.0  | 9.0 | 8.9 | 8.9 | 8.9 | 8.8 | 8.8 | 8.7 | 8.7 | 8.6 |
| 22.7 grams            | 9.4                                | 9.4  | 9.4  | 9.3  | 9.3  | 9.3  | 9.2  | 9.2  | 9.1  | 9.1  | 9.1  | 9.0  | 9.0 | 9.0 | 8.9 | 8.9 | 8.9 | 8.8 | 8.8 | 8.8 | 8.7 |
| 22.8 grams            | 9.5                                | 9.5  | 9.4  | 9.4  | 9.3  | 9.3  | 9.3  | 9.2  | 9.2  | 9.1  | 9.1  | 9.1  | 9.0 | 9.0 | 9.0 | 8.9 | 8.9 | 8.9 | 8.8 | 8.8 | 8.8 |
| 22.9 grams            | 9.5                                | 9.5  | 9.5  | 9.4  | 9.4  | 9.3  | 9.3  | 9.3  | 9.2  | 9.2  | 9.2  | 9.1  | 9.1 | 9.1 | 9.0 | 9.0 | 8.9 | 8.9 | 8.9 | 8.8 | 8.8 |
| 23.0 grams            | 9.6                                | 9.5  | 9.5  | 9.5  | 9.4  | 9.4  | 9.3  | 9.3  | 9.3  | 9.2  | 9.2  | 9.2  | 9.1 | 9.1 | 9.0 | 9.0 | 9.0 | 8.9 | 8.9 | 8.9 | 8.8 |
| 23.1 grams            | 9.6                                | 9.6  | 9.5  | 9.5  | 9.5  | 9.4  | 9.4  | 9.3  | 9.3  | 9.3  | 9.2  | 9.2  | 9.2 | 9.1 | 9.1 | 9.0 | 9.0 | 9.0 | 8.9 | 8.9 | 8.9 |
| 23.2 grams            | 9.7                                | 9.6  | 9.6  | 9.5  | 9.5  | 9.5  | 9.4  | 9.4  | 9.3  | 9.3  | 9.3  | 9.2  | 9.2 | 9.2 | 9.1 | 9.1 | 9.1 | 9.0 | 9.0 | 8.9 | 8.9 |
| 23.3 grams            | 9.7                                | 9.7  | 9.6  | 9.6  | 9.5  | 9.5  | 9.5  | 9.4  | 9.4  | 9.3  | 9.3  | 9.3  | 9.2 | 9.2 | 9.2 | 9.1 | 9.1 | 9.1 | 9.0 | 9.0 | 9.0 |
| 23.4 grams            | 9.7                                | 9.7  | 9.7  | 9.6  | 9.6  | 9.5  | 9.5  | 9.5  | 9.4  | 9.4  | 9.4  | 9.3  | 9.3 | 9.2 | 9.2 | 9.2 | 9.1 | 9.1 | 9.1 | 9.0 | 9.0 |
| 23.5 grams            | 9.8                                | 9.7  | 9.7  | 9.7  | 9.6  | 9.6  | 9.5  | 9.5  | 9.5  | 9.4  | 9.4  | 9.4  | 9.3 | 9.3 | 9.2 | 9.2 | 9.2 | 9.1 | 9.1 | 9.1 | 9.0 |
| 23.6 grams            | 9.8                                | 9.8  | 9.7  | 9.7  | 9.7  | 9.6  | 9.6  | 9.5  | 9.5  | 9.5  | 9.4  | 9.4  | 9.4 | 9.3 | 9.3 | 9.2 | 9.2 | 9.2 | 9.1 | 9.1 | 9.1 |
| 23.7 grams            | 9.9                                | 9.8  | 9.8  | 9.7  | 9.7  | 9.7  | 9.6  | 9.6  | 9.5  | 9.5  | 9.4  | 9.4  | 9.4 | 9.3 | 9.3 | 9.2 | 9.2 | 9.2 | 9.1 | 9.1 | 9.1 |
| 23.8 grams            | 9.9                                | 9.9  | 9.8  | 9.8  | 9.7  | 9.7  | 9.7  | 9.6  | 9.6  | 9.5  | 9.5  | 9.5  | 9.4 | 9.4 | 9.4 | 9.3 | 9.3 | 9.3 | 9.2 | 9.2 | 9.1 |
| 23.9 grams            | 9.9                                | 9.9  | 9.9  | 9.8  | 9.8  | 9.7  | 9.7  | 9.7  | 9.6  | 9.6  | 9.6  | 9.5  | 9.5 | 9.4 | 9.4 | 9.4 | 9.3 | 9.3 | 9.3 | 9.2 | 9.2 |
| 24.0 grams            | 10.0                               | 9.9  | 9.9  | 9.9  | 9.8  | 9.8  | 9.8  | 9.7  | 9.7  | 9.6  | 9.6  | 9.6  | 9.5 | 9.5 | 9.4 | 9.4 | 9.4 | 9.3 | 9.3 | 9.3 | 9.2 |
| 24.1 grams            | 10.0                               | 10.0 | 9.9  | 9.9  | 9.9  | 9.8  | 9.8  | 9.7  | 9.7  | 9.7  | 9.6  | 9.6  | 9.6 | 9.5 | 9.5 | 9.4 | 9.4 | 9.4 | 9.3 | 9.3 | 9.3 |
| 24.2 grams            | 10.1                               | 10.0 | 10.0 | 9.9  | 9.9  | 9.9  | 9.8  | 9.8  | 9.7  | 9.7  | 9.7  | 9.6  | 9.6 | 9.6 | 9.5 | 9.5 | 9.4 | 9.4 | 9.4 | 9.3 | 9.3 |
| 24.3 grams            | 10.1                               | 10.1 | 10.0 | 10.0 | 9.9  | 9.9  | 9.9  | 9.8  | 9.8  | 9.7  | 9.7  | 9.7  | 9.6 | 9.6 | 9.6 | 9.5 | 9.5 | 9.4 | 9.4 | 9.4 | 9.3 |
| 24.4 grams            | 10.2                               | 10.1 | 10.1 | 10.0 | 10.0 | 9.9  | 9.9  | 9.9  | 9.8  | 9.8  | 9.8  | 9.7  | 9.7 | 9.6 | 9.6 | 9.6 | 9.5 | 9.5 | 9.4 | 9.4 | 9.4 |
| 24.5 grams            | 10.2                               | 10.2 | 10.1 | 10.1 | 10.0 | 10.0 | 9.9  | 9.9  | 9.9  | 9.8  | 9.8  | 9.8  | 9.7 | 9.6 | 9.6 | 9.6 | 9.5 | 9.5 | 9.4 | 9.4 | 9.4 |
| 24.6 grams            | 10.2                               | 10.2 | 10.2 | 10.1 | 10.1 | 10.1 | 10.0 | 10.0 | 10.0 | 9.9  | 9.9  | 9.8  | 9.8 | 9.8 | 9.7 | 9.6 | 9.6 | 9.6 | 9.5 | 9.5 | 9.5 |
| 24.7 grams            | 10.3                               | 10.2 | 10.2 | 10.2 | 10.1 | 10.1 | 10.0 | 10.0 | 9.9  | 9.9  | 9.9  | 9.8  | 9.8 | 9.8 | 9.7 | 9.6 | 9.6 | 9.6 | 9.5 | 9.5 | 9.5 |
| 24.8 grams            | 10.3                               | 10.3 | 10.2 | 10.2 | 10.2 | 10.1 | 10.1 | 10.0 | 10.0 | 9.9  | 9.9  | 9.9  | 9.8 | 9.8 | 9.8 | 9.7 | 9.7 | 9.6 | 9.6 | 9.6 | 9.5 |
| 24.9 grams            | 10.4                               | 10.3 | 10.3 | 10.2 | 10.2 | 10.2 | 10.1 | 10.1 | 10.0 | 10.0 | 10.0 | 9.9  | 9.9 | 9.8 | 9.8 | 9.8 | 9.7 | 9.7 | 9.6 | 9.6 | 9.6 |
| 25.0 grams            | 10.4                               | 10.4 | 10.3 | 10.3 | 10.2 | 10.2 | 10.2 | 10.1 | 10.1 | 10.0 | 10.0 | 10.0 | 9.9 | 9.9 | 9.8 | 9.8 | 9.8 | 9.7 | 9.7 | 9.6 | 9.6 |







TABLE II.—*Equivalent percentage of a sample of corn, etc., when the weights of the sample analyzed and of the mechanical separation are given—Continued.*

| Weight of separation. | Weight of sample analyzed (grams). |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |  |
|-----------------------|------------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|--|
|                       | 240                                | 241  | 242  | 243  | 244  | 245  | 246  | 247  | 248  | 249  | 250  | 251  | 252  | 253  | 254  | 255  | 256  | 257  | 258  | 259  | 260  |      |  |  |
| 30.1 grams            | 12.5                               | 12.5 | 12.4 | 12.4 | 12.3 | 12.3 | 12.2 | 12.2 | 12.1 | 12.1 | 12.0 | 12.0 | 11.9 | 11.9 | 11.8 | 11.8 | 11.7 | 11.7 | 11.7 | 11.6 | 11.6 | 11.6 |  |  |
| 30.2 grams            | 12.6                               | 12.5 | 12.5 | 12.4 | 12.4 | 12.3 | 12.3 | 12.2 | 12.2 | 12.1 | 12.1 | 12.0 | 12.0 | 11.9 | 11.9 | 11.8 | 11.8 | 11.7 | 11.7 | 11.7 | 11.6 | 11.6 |  |  |
| 30.3 grams            | 12.6                               | 12.6 | 12.5 | 12.5 | 12.4 | 12.4 | 12.3 | 12.3 | 12.2 | 12.2 | 12.1 | 12.1 | 12.0 | 12.0 | 11.9 | 11.9 | 11.8 | 11.8 | 11.7 | 11.7 | 11.6 | 11.6 |  |  |
| 30.4 grams            | 12.7                               | 12.6 | 12.6 | 12.5 | 12.4 | 12.4 | 12.3 | 12.3 | 12.2 | 12.2 | 12.2 | 12.1 | 12.1 | 12.0 | 12.0 | 11.9 | 11.9 | 11.8 | 11.8 | 11.7 | 11.6 | 11.6 |  |  |
| 30.5 grams            | 12.7                               | 12.6 | 12.6 | 12.5 | 12.5 | 12.4 | 12.4 | 12.3 | 12.3 | 12.2 | 12.2 | 12.1 | 12.1 | 12.0 | 12.0 | 12.0 | 11.9 | 11.9 | 11.8 | 11.8 | 11.7 | 11.6 |  |  |
| 30.6 grams            | 12.7                               | 12.7 | 12.6 | 12.6 | 12.5 | 12.5 | 12.4 | 12.3 | 12.3 | 12.2 | 12.2 | 12.2 | 12.1 | 12.1 | 12.0 | 12.0 | 11.9 | 11.9 | 11.8 | 11.8 | 11.7 | 11.6 |  |  |
| 30.7 grams            | 12.8                               | 12.7 | 12.7 | 12.6 | 12.6 | 12.5 | 12.5 | 12.4 | 12.4 | 12.3 | 12.3 | 12.2 | 12.2 | 12.1 | 12.1 | 12.0 | 12.0 | 11.9 | 11.9 | 11.8 | 11.8 | 11.8 |  |  |
| 30.8 grams            | 12.8                               | 12.8 | 12.7 | 12.7 | 12.6 | 12.6 | 12.5 | 12.5 | 12.4 | 12.4 | 12.3 | 12.3 | 12.2 | 12.2 | 12.1 | 12.1 | 12.0 | 12.0 | 11.9 | 11.9 | 11.8 | 11.8 |  |  |
| 30.9 grams            | 12.9                               | 12.8 | 12.8 | 12.7 | 12.7 | 12.6 | 12.6 | 12.5 | 12.4 | 12.4 | 12.4 | 12.3 | 12.3 | 12.2 | 12.2 | 12.1 | 12.1 | 12.0 | 12.0 | 11.9 | 11.9 | 11.9 |  |  |
| 31.0 grams            | 12.9                               | 12.9 | 12.8 | 12.7 | 12.7 | 12.6 | 12.6 | 12.5 | 12.4 | 12.4 | 12.4 | 12.3 | 12.3 | 12.2 | 12.2 | 12.1 | 12.1 | 12.0 | 12.0 | 11.9 | 11.9 | 11.9 |  |  |
| 31.1 grams            | 12.9                               | 12.9 | 12.8 | 12.8 | 12.7 | 12.7 | 12.6 | 12.6 | 12.5 | 12.5 | 12.4 | 12.4 | 12.3 | 12.3 | 12.2 | 12.2 | 12.1 | 12.1 | 12.0 | 12.0 | 12.0 | 12.0 |  |  |
| 31.2 grams            | 13.0                               | 12.9 | 12.9 | 12.8 | 12.8 | 12.7 | 12.7 | 12.6 | 12.6 | 12.5 | 12.5 | 12.4 | 12.4 | 12.3 | 12.3 | 12.2 | 12.2 | 12.1 | 12.1 | 12.0 | 12.0 | 12.0 |  |  |
| 31.3 grams            | 13.0                               | 13.0 | 12.9 | 12.9 | 12.8 | 12.8 | 12.7 | 12.7 | 12.6 | 12.6 | 12.5 | 12.5 | 12.4 | 12.4 | 12.3 | 12.3 | 12.2 | 12.2 | 12.1 | 12.1 | 12.0 | 12.0 |  |  |
| 31.4 grams            | 13.1                               | 13.0 | 13.0 | 12.9 | 12.9 | 12.8 | 12.8 | 12.7 | 12.7 | 12.6 | 12.6 | 12.5 | 12.5 | 12.4 | 12.3 | 12.3 | 12.2 | 12.2 | 12.1 | 12.1 | 12.0 | 12.0 |  |  |
| 31.5 grams            | 13.1                               | 13.1 | 13.0 | 13.0 | 12.9 | 12.8 | 12.8 | 12.7 | 12.7 | 12.6 | 12.6 | 12.5 | 12.5 | 12.4 | 12.4 | 12.3 | 12.3 | 12.2 | 12.2 | 12.1 | 12.1 | 12.1 |  |  |
| 31.6 grams            | 13.2                               | 13.1 | 13.0 | 13.0 | 12.9 | 12.9 | 12.8 | 12.8 | 12.7 | 12.7 | 12.6 | 12.6 | 12.5 | 12.5 | 12.4 | 12.4 | 12.3 | 12.3 | 12.2 | 12.2 | 12.1 | 12.1 |  |  |
| 31.7 grams            | 13.2                               | 13.1 | 13.1 | 13.0 | 13.0 | 12.9 | 12.9 | 12.8 | 12.8 | 12.7 | 12.7 | 12.6 | 12.6 | 12.5 | 12.5 | 12.4 | 12.4 | 12.3 | 12.3 | 12.2 | 12.2 | 12.2 |  |  |
| 31.8 grams            | 13.2                               | 13.2 | 13.1 | 13.1 | 13.0 | 13.0 | 12.9 | 12.9 | 12.8 | 12.8 | 12.7 | 12.7 | 12.6 | 12.6 | 12.5 | 12.5 | 12.4 | 12.4 | 12.3 | 12.3 | 12.2 | 12.2 |  |  |
| 31.9 grams            | 13.3                               | 13.2 | 13.2 | 13.1 | 13.1 | 13.0 | 13.0 | 12.9 | 12.9 | 12.9 | 12.8 | 12.8 | 12.7 | 12.6 | 12.6 | 12.5 | 12.5 | 12.4 | 12.4 | 12.3 | 12.3 | 12.3 |  |  |
| 32.0 grams            | 13.3                               | 13.3 | 13.2 | 13.2 | 13.1 | 13.1 | 13.0 | 12.9 | 12.9 | 12.9 | 12.8 | 12.8 | 12.7 | 12.7 | 12.6 | 12.6 | 12.5 | 12.5 | 12.4 | 12.4 | 12.3 | 12.3 |  |  |
| 32.1 grams            | 13.4                               | 13.3 | 13.3 | 13.2 | 13.1 | 13.1 | 13.0 | 13.0 | 12.9 | 12.9 | 12.8 | 12.8 | 12.7 | 12.7 | 12.6 | 12.6 | 12.5 | 12.5 | 12.4 | 12.4 | 12.3 | 12.3 |  |  |
| 32.2 grams            | 13.4                               | 13.4 | 13.3 | 13.2 | 13.2 | 13.1 | 13.1 | 13.0 | 13.0 | 12.9 | 12.9 | 12.8 | 12.8 | 12.7 | 12.7 | 12.6 | 12.6 | 12.5 | 12.5 | 12.4 | 12.4 | 12.4 |  |  |
| 32.3 grams            | 13.4                               | 13.4 | 13.3 | 13.3 | 13.2 | 13.2 | 13.1 | 13.1 | 13.0 | 13.0 | 12.9 | 12.9 | 12.8 | 12.8 | 12.7 | 12.7 | 12.6 | 12.6 | 12.5 | 12.5 | 12.4 | 12.4 |  |  |
| 32.4 grams            | 13.5                               | 13.4 | 13.4 | 13.3 | 13.3 | 13.2 | 13.2 | 13.1 | 13.1 | 13.0 | 13.0 | 12.9 | 12.8 | 12.8 | 12.7 | 12.7 | 12.6 | 12.6 | 12.5 | 12.5 | 12.4 | 12.4 |  |  |
| 32.5 grams            | 13.5                               | 13.5 | 13.4 | 13.4 | 13.3 | 13.3 | 13.2 | 13.1 | 13.1 | 13.0 | 13.0 | 12.9 | 12.9 | 12.8 | 12.8 | 12.7 | 12.7 | 12.6 | 12.6 | 12.5 | 12.5 | 12.5 |  |  |
| 32.6 grams            | 13.6                               | 13.5 | 13.4 | 13.4 | 13.3 | 13.3 | 13.2 | 13.2 | 13.1 | 13.1 | 13.0 | 13.0 | 12.9 | 12.9 | 12.8 | 12.8 | 12.7 | 12.7 | 12.6 | 12.6 | 12.5 | 12.5 |  |  |
| 32.7 grams            | 13.6                               | 13.6 | 13.5 | 13.4 | 13.4 | 13.3 | 13.3 | 13.2 | 13.2 | 13.1 | 13.1 | 13.0 | 13.0 | 12.9 | 12.9 | 12.8 | 12.8 | 12.7 | 12.7 | 12.6 | 12.6 | 12.6 |  |  |
| 32.8 grams            | 13.7                               | 13.6 | 13.5 | 13.5 | 13.4 | 13.4 | 13.3 | 13.3 | 13.2 | 13.2 | 13.1 | 13.1 | 13.0 | 13.0 | 12.9 | 12.9 | 12.8 | 12.8 | 12.7 | 12.7 | 12.6 | 12.6 |  |  |
| 32.9 grams            | 13.7                               | 13.6 | 13.6 | 13.5 | 13.5 | 13.4 | 13.4 | 13.3 | 13.3 | 13.2 | 13.2 | 13.1 | 13.0 | 13.0 | 12.9 | 12.9 | 12.8 | 12.8 | 12.7 | 12.7 | 12.6 | 12.6 |  |  |
| 33.0 grams            | 13.7                               | 13.7 | 13.6 | 13.6 | 13.5 | 13.5 | 13.4 | 13.4 | 13.3 | 13.3 | 13.2 | 13.1 | 13.1 | 13.0 | 13.0 | 12.9 | 12.9 | 12.8 | 12.8 | 12.7 | 12.7 | 12.7 |  |  |
| 33.1 grams            | 13.8                               | 13.7 | 13.7 | 13.6 | 13.6 | 13.5 | 13.4 | 13.4 | 13.3 | 13.3 | 13.2 | 13.2 | 13.1 | 13.1 | 13.0 | 13.0 | 12.9 | 12.9 | 12.8 | 12.8 | 12.7 | 12.7 |  |  |
| 33.2 grams            | 13.8                               | 13.8 | 13.7 | 13.7 | 13.6 | 13.5 | 13.5 | 13.4 | 13.4 | 13.3 | 13.3 | 13.2 | 13.2 | 13.1 | 13.1 | 13.0 | 13.0 | 12.9 | 12.9 | 12.8 | 12.8 | 12.8 |  |  |
| 33.3 grams            | 13.9                               | 13.8 | 13.8 | 13.7 | 13.6 | 13.6 | 13.5 | 13.5 | 13.4 | 13.4 | 13.3 | 13.3 | 13.2 | 13.2 | 13.1 | 13.1 | 13.0 | 12.9 | 12.9 | 12.8 | 12.8 | 12.8 |  |  |
| 33.4 grams            | 13.9                               | 13.8 | 13.8 | 13.7 | 13.7 | 13.6 | 13.6 | 13.5 | 13.4 | 13.4 | 13.3 | 13.3 | 13.2 | 13.2 | 13.1 | 13.1 | 13.0 | 12.9 | 12.9 | 12.8 | 12.8 | 12.8 |  |  |
| 33.5 grams            | 13.9                               | 13.9 | 13.8 | 13.8 | 13.7 | 13.7 | 13.6 | 13.6 | 13.5 | 13.4 | 13.4 | 13.3 | 13.3 | 13.2 | 13.2 | 13.1 | 13.1 | 13.0 | 13.0 | 12.9 | 12.9 | 12.9 |  |  |
| 33.6 grams            | 14.0                               | 13.9 | 13.9 | 13.8 | 13.8 | 13.7 | 13.6 | 13.6 | 13.5 | 13.5 | 13.4 | 13.4 | 13.3 | 13.3 | 13.2 | 13.2 | 13.1 | 13.1 | 13.0 | 13.0 | 12.9 | 12.9 |  |  |
| 33.7 grams            | 14.0                               | 14.0 | 13.9 | 13.9 | 13.8 | 13.7 | 13.7 | 13.6 | 13.6 | 13.5 | 13.5 | 13.4 | 13.4 | 13.3 | 13.3 | 13.2 | 13.2 | 13.1 | 13.1 | 13.0 | 13.0 | 13.0 |  |  |
| 33.8 grams            | 14.1                               | 14.0 | 14.0 | 13.9 | 13.8 | 13.8 | 13.7 | 13.7 | 13.6 | 13.6 | 13.5 | 13.5 | 13.4 | 13.4 | 13.3 | 13.3 | 13.2 | 13.2 | 13.1 | 13.1 | 13.0 | 13.0 |  |  |
| 33.9 grams            | 14.1                               | 14.1 | 14.0 | 13.9 | 13.9 | 13.8 | 13.8 | 13.7 | 13.7 | 13.6 | 13.6 | 13.5 | 13.5 | 13.4 | 13.4 | 13.3 | 13.3 | 13.2 | 13.2 | 13.1 | 13.1 | 13.1 |  |  |
| 34.0 grams            | 14.2                               | 14.1 | 14.0 | 14.0 | 13.9 | 13.9 | 13.8 | 13.8 | 13.7 | 13.6 | 13.6 | 13.5 | 13.5 | 13.4 | 13.4 | 13.3 | 13.3 | 13.2 | 13.2 | 13.1 | 13.1 | 13.1 |  |  |
| 34.1 grams            | 14.2                               | 14.1 | 14.1 | 14.0 | 14.0 | 13.9 | 13.9 | 13.8 | 13.7 | 13.7 | 13.6 | 13.6 | 13.5 | 13.5 | 13.4 | 13.4 | 13.3 | 13.3 | 13.2 | 13.2 | 13.1 | 13.1 |  |  |
| 34.2 grams            | 14.2                               | 14.2 | 14.1 | 14.1 | 14.0 | 13.9 | 13.9 | 13.8 | 13.7 | 13.7 | 13.6 | 13.6 | 13.5 | 13.5 | 13.4 | 13.4 | 13.3 | 13.3 | 13.2 | 13.2 | 13.1 | 13.1 |  |  |
| 34.3 grams            | 14.3                               | 14.2 | 14.2 | 14.1 | 14.0 | 14.0 | 13.9 | 13.9 | 13.8 | 13.8 | 13.7 | 13.7 | 13.6 | 13.6 | 13.5 | 13.5 | 13.4 | 13.4 | 13.3 | 13.3 | 13.2 | 13.2 |  |  |
| 34.4 grams            | 14.3                               | 14.3 | 14.2 | 14.1 | 14.1 | 14.0 | 14.0 | 13.9 | 13.9 | 13.8 | 13.8 | 13.7 | 13.6 | 13.6 | 13.5 | 13.5 | 13.4 | 13.4 | 13.3 | 13.3 | 13.2 | 13.2 |  |  |
| 34.5 grams            | 14.4                               | 14.3 | 14.2 | 14.2 | 14.1 | 14.1 | 14.0 | 14.0 | 13.9 | 13.8 | 13.8 | 13.7 | 13.6 | 13.6 | 13.5 | 13.5 | 13.4 | 13.4 | 13.3 | 13.3 | 13.2 | 13.2 |  |  |
| 34.6 grams            | 14.4                               | 14.3 | 14.3 | 14.2 | 14.2 | 14.1 | 14.1 | 14.0 | 13.9 | 13.9 | 13.8 | 13.8 | 13.7 | 13.6 | 13.6 | 13.5 | 13.5 | 13.4 | 13.4 | 13.3 | 13.3 | 13.3 |  |  |
| 34.7 grams            | 14.4                               | 14.4 | 14.3 | 14.3 | 14.2 | 14.2 | 14.1 | 14.0 | 14.0 | 13.9 | 13.9 | 13.8 | 13.8 | 13.7 | 13.7 | 13.6 | 13.6 | 13.5 | 13.5 | 13.4 | 13.4 | 13.4 |  |  |
| 34.8 grams            | 14.5                               | 14.4 | 14.4 | 14.3 | 14.3 | 14.2 | 14.1 | 14.1 | 14.0 | 14.0 | 13.9 | 13.9 | 13.8 | 13.7 | 13.7 | 13.6 | 13.6 | 13.5 | 13.5 | 13.4 | 13.4 | 13.4 |  |  |
| 34.9 grams            | 14.5                               | 14.5 | 14.4 | 14.4 | 14.3 | 14.3 | 14.2 | 14.2 | 14.1 | 14.1 | 14.0 | 14.0 | 13.9 | 13.8 | 13.8 | 13.7 | 13.6 | 13.6 | 13.5 | 13.5 | 13.4 | 13.4 |  |  |
| 35.0 grams            | 14.6                               | 14.5 | 14.5 | 14.4 | 14.4 | 14.3 | 14.3 | 14.2 | 14.2 | 14.1 | 14.1 | 14.0 | 14.0 | 13.9 | 13.8 | 13.8 | 13.7 | 13.6 | 13.6 | 13.5 | 13.5 | 13.5 |  |  |

TABLE II.—*Equivalent percentage of a sample of corn, etc., when the weights of the sample analyzed and of the mechanical separation are given—Continued.*

| Weight of separation. | Weight of sample analyzed (grams). |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
|-----------------------|------------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
|                       | 240                                | 241  | 242  | 243  | 244  | 245  | 246  | 247  | 248  | 249  | 250  | 251  | 252  | 253  | 254  | 255  | 256  | 257  | 258  | 259  | 260  |
| 35.1 grams            | 14.6                               | 14.6 | 14.5 | 14.4 | 14.4 | 14.3 | 14.3 | 14.2 | 14.1 | 14.1 | 14.0 | 14.0 | 13.9 | 13.9 | 13.8 | 13.8 | 13.7 | 13.6 | 13.6 | 13.5 | 13.5 |
| 35.2 grams            | 14.7                               | 14.6 | 14.5 | 14.5 | 14.4 | 14.4 | 14.3 | 14.2 | 14.2 | 14.1 | 14.1 | 14.0 | 14.0 | 13.9 | 13.8 | 13.8 | 13.7 | 13.7 | 13.6 | 13.6 | 13.5 |
| 35.3 grams            | 14.7                               | 14.6 | 14.6 | 14.5 | 14.5 | 14.4 | 14.3 | 14.3 | 14.2 | 14.2 | 14.1 | 14.1 | 14.0 | 13.9 | 13.9 | 13.8 | 13.8 | 13.7 | 13.7 | 13.6 | 13.6 |
| 35.4 grams            | 14.7                               | 14.7 | 14.6 | 14.6 | 14.5 | 14.4 | 14.4 | 14.3 | 14.3 | 14.2 | 14.2 | 14.1 | 14.0 | 14.0 | 13.9 | 13.9 | 13.8 | 13.8 | 13.7 | 13.7 | 13.6 |
| 35.5 grams            | 14.8                               | 14.7 | 14.7 | 14.6 | 14.5 | 14.5 | 14.4 | 14.4 | 14.3 | 14.2 | 14.2 | 14.1 | 14.1 | 14.0 | 14.0 | 13.9 | 13.9 | 13.8 | 13.7 | 13.7 | 13.6 |
| 35.6 grams            | 14.8                               | 14.8 | 14.7 | 14.6 | 14.6 | 14.5 | 14.5 | 14.4 | 14.3 | 14.3 | 14.2 | 14.2 | 14.1 | 14.1 | 14.0 | 14.0 | 13.9 | 13.8 | 13.8 | 13.7 | 13.7 |
| 35.7 grams            | 14.9                               | 14.8 | 14.7 | 14.7 | 14.6 | 14.6 | 14.5 | 14.4 | 14.4 | 14.3 | 14.3 | 14.2 | 14.2 | 14.1 | 14.0 | 14.0 | 13.9 | 13.9 | 13.8 | 13.8 | 13.7 |
| 35.8 grams            | 14.9                               | 14.8 | 14.8 | 14.7 | 14.7 | 14.6 | 14.5 | 14.5 | 14.4 | 14.4 | 14.3 | 14.3 | 14.2 | 14.1 | 14.1 | 14.0 | 13.9 | 13.9 | 13.8 | 13.8 | 13.7 |
| 35.9 grams            | 14.9                               | 14.9 | 14.8 | 14.8 | 14.7 | 14.6 | 14.6 | 14.5 | 14.5 | 14.4 | 14.4 | 14.3 | 14.2 | 14.2 | 14.1 | 14.1 | 14.0 | 14.0 | 13.9 | 13.9 | 13.8 |
| 36.0 grams            | 15.0                               | 14.9 | 14.9 | 14.8 | 14.7 | 14.7 | 14.6 | 14.6 | 14.5 | 14.4 | 14.4 | 14.3 | 14.3 | 14.2 | 14.2 | 14.1 | 14.1 | 14.0 | 13.9 | 13.9 | 13.8 |
| 36.1 grams            | 15.0                               | 15.0 | 14.9 | 14.8 | 14.8 | 14.7 | 14.7 | 14.6 | 14.5 | 14.5 | 14.4 | 14.4 | 14.3 | 14.3 | 14.2 | 14.1 | 14.1 | 14.0 | 14.0 | 13.9 | 13.9 |
| 36.2 grams            | 15.1                               | 15.0 | 14.9 | 14.9 | 14.8 | 14.7 | 14.7 | 14.6 | 14.5 | 14.5 | 14.4 | 14.4 | 14.3 | 14.3 | 14.2 | 14.1 | 14.1 | 14.0 | 14.0 | 13.9 | 13.9 |
| 36.3 grams            | 15.1                               | 15.1 | 15.0 | 14.9 | 14.9 | 14.8 | 14.7 | 14.7 | 14.6 | 14.5 | 14.5 | 14.4 | 14.3 | 14.3 | 14.2 | 14.1 | 14.1 | 14.0 | 14.0 | 13.9 | 13.9 |
| 36.4 grams            | 15.2                               | 15.1 | 15.0 | 15.0 | 14.9 | 14.8 | 14.8 | 14.7 | 14.7 | 14.6 | 14.6 | 14.5 | 14.4 | 14.4 | 14.3 | 14.3 | 14.2 | 14.2 | 14.1 | 14.0 | 14.0 |
| 36.5 grams            | 15.2                               | 15.1 | 15.1 | 15.0 | 14.9 | 14.9 | 14.8 | 14.8 | 14.7 | 14.6 | 14.6 | 14.5 | 14.5 | 14.4 | 14.4 | 14.3 | 14.2 | 14.2 | 14.1 | 14.1 | 14.0 |
| 36.6 grams            | 15.2                               | 15.2 | 15.1 | 15.1 | 15.0 | 14.9 | 14.8 | 14.8 | 14.7 | 14.6 | 14.6 | 14.5 | 14.5 | 14.4 | 14.4 | 14.3 | 14.2 | 14.2 | 14.1 | 14.1 | 14.0 |
| 36.7 grams            | 15.3                               | 15.2 | 15.2 | 15.1 | 15.0 | 15.0 | 14.9 | 14.8 | 14.8 | 14.7 | 14.7 | 14.6 | 14.6 | 14.5 | 14.4 | 14.4 | 14.3 | 14.3 | 14.2 | 14.2 | 14.1 |
| 36.8 grams            | 15.3                               | 15.3 | 15.2 | 15.1 | 15.1 | 15.0 | 14.9 | 14.9 | 14.8 | 14.8 | 14.7 | 14.7 | 14.6 | 14.5 | 14.5 | 14.4 | 14.4 | 14.3 | 14.3 | 14.2 | 14.1 |
| 36.9 grams            | 15.4                               | 15.3 | 15.2 | 15.2 | 15.1 | 15.1 | 15.0 | 14.9 | 14.9 | 14.8 | 14.8 | 14.7 | 14.6 | 14.6 | 14.5 | 14.5 | 14.4 | 14.3 | 14.3 | 14.2 | 14.2 |
| 37.0 grams            | 15.4                               | 15.3 | 15.3 | 15.2 | 15.2 | 15.1 | 15.0 | 14.9 | 14.9 | 14.8 | 14.8 | 14.7 | 14.6 | 14.6 | 14.5 | 14.5 | 14.4 | 14.4 | 14.3 | 14.3 | 14.2 |
| 37.1 grams            | 15.4                               | 15.4 | 15.3 | 15.3 | 15.2 | 15.1 | 15.1 | 15.0 | 14.9 | 14.9 | 14.8 | 14.8 | 14.7 | 14.7 | 14.6 | 14.5 | 14.5 | 14.4 | 14.4 | 14.3 | 14.3 |
| 37.2 grams            | 15.5                               | 15.4 | 15.4 | 15.3 | 15.2 | 15.2 | 15.1 | 15.1 | 15.0 | 14.9 | 14.9 | 14.8 | 14.8 | 14.7 | 14.6 | 14.6 | 14.5 | 14.5 | 14.4 | 14.4 | 14.3 |
| 37.3 grams            | 15.5                               | 15.5 | 15.4 | 15.3 | 15.3 | 15.2 | 15.2 | 15.1 | 15.0 | 14.9 | 14.9 | 14.8 | 14.7 | 14.7 | 14.6 | 14.5 | 14.5 | 14.4 | 14.4 | 14.3 | 14.3 |
| 37.4 grams            | 15.6                               | 15.5 | 15.4 | 15.4 | 15.3 | 15.3 | 15.2 | 15.1 | 15.1 | 15.0 | 14.9 | 14.9 | 14.8 | 14.8 | 14.7 | 14.6 | 14.5 | 14.5 | 14.4 | 14.4 | 14.3 |
| 37.5 grams            | 15.6                               | 15.6 | 15.5 | 15.4 | 15.4 | 15.3 | 15.2 | 15.2 | 15.1 | 15.1 | 15.0 | 14.9 | 14.9 | 14.8 | 14.8 | 14.7 | 14.6 | 14.6 | 14.5 | 14.5 | 14.4 |
| 37.6 grams            | 15.7                               | 15.6 | 15.5 | 15.5 | 15.4 | 15.3 | 15.3 | 15.2 | 15.2 | 15.1 | 15.1 | 15.0 | 14.9 | 14.9 | 14.8 | 14.7 | 14.7 | 14.6 | 14.6 | 14.5 | 14.5 |
| 37.7 grams            | 15.7                               | 15.6 | 15.6 | 15.5 | 15.4 | 15.4 | 15.3 | 15.3 | 15.2 | 15.1 | 15.1 | 15.0 | 15.0 | 14.9 | 14.8 | 14.8 | 14.7 | 14.7 | 14.6 | 14.5 | 14.5 |
| 37.8 grams            | 15.7                               | 15.7 | 15.6 | 15.5 | 15.5 | 15.4 | 15.3 | 15.2 | 15.2 | 15.1 | 15.1 | 15.0 | 15.0 | 14.9 | 14.9 | 14.8 | 14.8 | 14.7 | 14.6 | 14.6 | 14.5 |
| 37.9 grams            | 15.8                               | 15.7 | 15.7 | 15.6 | 15.5 | 15.5 | 15.4 | 15.3 | 15.3 | 15.2 | 15.2 | 15.1 | 15.0 | 15.0 | 14.9 | 14.9 | 14.8 | 14.7 | 14.7 | 14.6 | 14.6 |
| 38.0 grams            | 15.8                               | 15.8 | 15.7 | 15.6 | 15.5 | 15.5 | 15.4 | 15.3 | 15.3 | 15.2 | 15.2 | 15.1 | 15.1 | 15.0 | 15.0 | 14.9 | 14.8 | 14.8 | 14.7 | 14.7 | 14.6 |
| 38.1 grams            | 15.9                               | 15.8 | 15.7 | 15.7 | 15.6 | 15.5 | 15.5 | 15.4 | 15.3 | 15.2 | 15.2 | 15.1 | 15.0 | 15.0 | 15.0 | 14.9 | 14.9 | 14.8 | 14.8 | 14.7 | 14.6 |
| 38.2 grams            | 15.9                               | 15.8 | 15.8 | 15.7 | 15.6 | 15.5 | 15.5 | 15.4 | 15.3 | 15.3 | 15.2 | 15.1 | 15.1 | 15.0 | 15.0 | 14.9 | 14.9 | 14.8 | 14.8 | 14.7 | 14.6 |
| 38.3 grams            | 15.9                               | 15.9 | 15.8 | 15.8 | 15.7 | 15.6 | 15.5 | 15.5 | 15.4 | 15.3 | 15.2 | 15.2 | 15.1 | 15.1 | 15.0 | 15.0 | 14.9 | 14.8 | 14.8 | 14.7 | 14.6 |
| 38.4 grams            | 16.0                               | 15.9 | 15.9 | 15.8 | 15.7 | 15.7 | 15.6 | 15.5 | 15.5 | 15.4 | 15.3 | 15.2 | 15.2 | 15.1 | 15.1 | 15.0 | 15.0 | 14.9 | 14.9 | 14.8 | 14.8 |
| 38.5 grams            | 16.0                               | 16.0 | 15.9 | 15.8 | 15.8 | 15.7 | 15.6 | 15.5 | 15.5 | 15.4 | 15.3 | 15.3 | 15.2 | 15.1 | 15.1 | 15.0 | 15.0 | 14.9 | 14.9 | 14.8 | 14.8 |
| 38.6 grams            | 16.1                               | 16.0 | 15.9 | 15.9 | 15.8 | 15.7 | 15.7 | 15.6 | 15.5 | 15.5 | 15.4 | 15.3 | 15.2 | 15.2 | 15.1 | 15.1 | 15.0 | 15.0 | 14.9 | 14.9 | 14.8 |
| 38.7 grams            | 16.1                               | 16.0 | 16.0 | 15.9 | 15.9 | 15.8 | 15.7 | 15.7 | 15.6 | 15.5 | 15.5 | 15.4 | 15.3 | 15.2 | 15.2 | 15.1 | 15.1 | 15.0 | 14.9 | 14.9 | 14.9 |
| 38.8 grams            | 16.2                               | 16.1 | 16.0 | 16.0 | 15.9 | 15.8 | 15.8 | 15.7 | 15.6 | 15.6 | 15.5 | 15.4 | 15.3 | 15.2 | 15.1 | 15.1 | 15.0 | 15.0 | 14.9 | 14.9 | 14.9 |
| 38.9 grams            | 16.2                               | 16.1 | 16.1 | 16.0 | 15.9 | 15.9 | 15.8 | 15.7 | 15.7 | 15.6 | 15.6 | 15.5 | 15.4 | 15.4 | 15.3 | 15.2 | 15.2 | 15.1 | 15.1 | 15.0 | 15.0 |
| 39.0 grams            | 16.2                               | 16.2 | 16.1 | 16.0 | 16.0 | 15.9 | 15.8 | 15.8 | 15.7 | 15.7 | 15.6 | 15.5 | 15.5 | 15.4 | 15.3 | 15.3 | 15.2 | 15.2 | 15.1 | 15.1 | 15.0 |
| 39.1 grams            | 16.3                               | 16.2 | 16.1 | 16.1 | 16.0 | 15.9 | 15.9 | 15.8 | 15.8 | 15.7 | 15.6 | 15.6 | 15.5 | 15.4 | 15.4 | 15.3 | 15.3 | 15.2 | 15.1 | 15.1 | 15.0 |
| 39.2 grams            | 16.3                               | 16.3 | 16.2 | 16.1 | 16.1 | 16.0 | 15.9 | 15.9 | 15.8 | 15.7 | 15.7 | 15.6 | 15.5 | 15.5 | 15.4 | 15.4 | 15.3 | 15.2 | 15.2 | 15.1 | 15.1 |
| 39.3 grams            | 16.4                               | 16.3 | 16.2 | 16.2 | 16.1 | 16.0 | 16.0 | 15.9 | 15.8 | 15.8 | 15.7 | 15.6 | 15.6 | 15.5 | 15.5 | 15.4 | 15.3 | 15.3 | 15.2 | 15.2 | 15.1 |
| 39.4 grams            | 16.4                               | 16.3 | 16.3 | 16.2 | 16.1 | 16.1 | 16.0 | 15.9 | 15.9 | 15.8 | 15.8 | 15.7 | 15.6 | 15.5 | 15.5 | 15.4 | 15.3 | 15.3 | 15.2 | 15.2 | 15.1 |
| 39.5 grams            | 16.4                               | 16.4 | 16.3 | 16.2 | 16.2 | 16.1 | 16.0 | 16.0 | 15.9 | 15.8 | 15.7 | 15.7 | 15.6 | 15.5 | 15.5 | 15.4 | 15.4 | 15.3 | 15.2 | 15.2 | 15.1 |
| 39.6 grams            | 16.5                               | 16.4 | 16.4 | 16.3 | 16.2 | 16.2 | 16.1 | 16.0 | 16.0 | 15.9 | 15.8 | 15.8 | 15.7 | 15.6 | 15.6 | 15.5 | 15.5 | 15.4 | 15.3 | 15.3 | 15.2 |
| 39.7 grams            | 16.5                               | 16.5 | 16.4 | 16.3 | 16.3 | 16.2 | 16.1 | 16.1 | 16.0 | 15.9 | 15.9 | 15.8 | 15.7 | 15.7 | 15.6 | 15.6 | 15.5 | 15.4 | 15.4 | 15.3 | 15.3 |
| 39.8 grams            | 16.6                               | 16.5 | 16.4 | 16.4 | 16.3 | 16.2 | 16.2 | 16.1 | 16.0 | 16.0 | 15.9 | 15.8 | 15.8 | 15.7 | 15.7 | 15.6 | 15.5 | 15.5 | 15.4 | 15.4 | 15.3 |
| 39.9 grams            | 16.6                               | 16.5 | 16.5 | 16.4 | 16.3 | 16.3 | 16.2 | 16.1 | 16.1 | 16.0 | 16.0 | 15.9 | 15.8 | 15.8 | 15.7 | 15.6 | 15.6 | 15.5 | 15.5 | 15.4 | 15.3 |
| 40.0 grams            | 16.7                               | 16.6 | 16.6 | 16.5 | 16.4 | 16.3 | 16.3 | 16.2 | 16.1 | 16.1 | 16.0 | 16.0 | 15.9 | 15.9 | 15.8 | 15.7 | 15.7 | 15.6 | 15.6 | 15.5 | 15.4 |

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# UNITED STATES DEPARTMENT OF AGRICULTURE



## BULLETIN No. 575

Contribution from the Bureau of Animal Industry  
JOHN R. MOHLER, Chief



Washington, D. C.

July 23, 1918

### STOCK-POISONING PLANTS OF THE RANGE

By C. D. MARSH, *Physiologist, Pathological Division.*

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#### PREFATORY NOTE.

It is well known that poisonous plants cause heavy losses of range animals. Statistics in regard to these losses are not available, but from estimates made in many localities it seems probable that the average loss must be as great as 3 to 5 per cent, while in some range States it rises to much higher figures. For example, it has been estimated that in Colorado the losses amount to a million dollars annually, while sheep growers in Wyoming have estimated their annual loss as 14.6 per cent.

These losses, too, are to a large extent of mature animals, those that are ready or nearly ready for the market, and for the rearing of which large sums have already been spent. The importance of these severe losses has been recognized by the United States Department of Agriculture and extended investigations and experiments have been undertaken to determine what plants were poisonous and under what conditions poisoning took place, and to formulate methods for preventing these deaths. This work has involved prolonged study, and is still in progress. Some very definite results have been obtained, however, and it has been shown that the heaviest losses are due to a comparatively small number of plants. If the stockmen and herders can recognize these plants and will act upon the information contained in the bulletins which have been published on the subject, there is no doubt that most of these losses can be avoided.

Presumably, for the sake of their own material interests, the owners of live stock will be glad to do all in their power to reduce the fatalities from these plants. At the present time, however, when it is a matter of supreme concern to conserve the national food supply, one of the most important elements of which is meat, it is especially



necessary to bring the industry of stock production to the highest possible stage of efficiency, and it becomes a civic duty for every owner of live stock to produce as much as possible.

As a factor to aid in the conservation of food, this bulletin has been prepared with a view to assisting in the ready recognition of the plants which are most to be feared, and with brief suggestions, by following which losses can be largely reduced.

While our knowledge of poisonous plants is still incomplete, if stockmen will make it a point to recognize the plants and instruct their herders, following out the suggested methods of treatment and prevention, it will result in a very material and important increase of the meat supply.

Plates VIII, XIII, XIV, XV, XXI, and XXIV are from paintings by F. A. Walpole, in the collection of the United States National Herbarium.

J. R. MOHLER,  
*Chief of Bureau.*

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## INTRODUCTION.

Poisonous plants have been the cause of heavy losses among live stock on the range. Stockmen generally have recognized the fact, but in the past comparatively little has been done to avoid the losses. The first intimation of trouble has ordinarily been the finding of the dead carcasses, and while the men handling the stock have felt reasonably sure that certain plants were responsible, their knowledge of the plants was very meager, and the evidence against any particular plant was frequently insufficient. It was noticed that these losses were more apt to occur in certain seasons than in others, and it was assumed in some cases that the plant was more poisonous at certain stages of growth than at others. Many of the stockmen were entirely uncertain as to what plant caused the damage, and it was common to speak of the source of the trouble as "poison weed," in a general way, without any very definite idea as to what particular weed was responsible for the loss. Moreover, the investigations which have been carried out on the subject of range-poisoning plants have necessarily been somewhat narrow in scope. There is a popular misconception in regard to the quantity of a poisonous plant necessary to produce illness. It seems to be the general belief that any plant possessing poisonous properties must be violently toxic. It is not unusual to hear stories of poisoning of domestic animals by a very few leaves of a poisonous plant. As a matter of fact, most of the stock-poisoning plants in the United States produce illness only when eaten in considerable quantity. This explains why so many experimental tests of animals with poisonous plants have failed, since some of these plants can be eaten with no apparent harm, provided the quantity eaten at any one time is not sufficient to produce toxic effects.

The problems of plants poisonous to live stock seem to be very largely peculiar to North America. Although similar plants occur in the eastern continents, very little information could be drawn from European sources to aid the American stockman.

For some years the United States Department of Agriculture has been carrying on a series of experiments with poisonous plants, and there has been accumulated a considerable body of information, which, although necessarily incomplete, will be, it is hoped, of service to men handling live stock upon the open range.

It appears from these researches that, while the total number of poisonous plants growing in the West may be very large, the number to be dreaded by the stockmen is comparatively small, and in most cases it is not at all difficult to identify the plants which are to be avoided. Of course, most stockmen are not botanists and are not interested in the botanical distinctions of plants. Most of them, however, are good observers and can readily recognize these plants if the salient characteristics are brought before them in a manner which they can understand.

With the continued reduction of the area of stock ranges and the increasing value of live stock, the owners are of necessity handling the animals with greater care. The time has passed when a man will buy a few cows, turn them loose, and pay no more attention to them except to brand the calves and occasionally round up a few of them for market. It is becoming necessary for stock owners to be in constant touch with their animals upon the range, and it is no longer probable that a large number will die and the fact become known to the owner only after the lapse of weeks or months. Most of the mountain stock ranges at the present time are under the general direction of the Forest Service, and the officers of that bureau are constantly patrolling the territory under their direction, so that between this supervision and the riding by the employees of the stock owners, cattle and horses upon the range are kept under almost constant observation. Sheep, of course, have always been under the immediate care of a herder, and probably will continue to be attended to in the same general way.

Extensive acquaintance by the author with the conditions on the western ranges has shown that while harmful plants are known and avoided by some men, there are large regions in which these plants have never been recognized, in spite of the fact that losses have occurred year after year.

The object of this publication is to present in a brief and intelligible form such a description of the common or more important plants as can be understood by a person not in the habit of using technical terms. With this description is given a brief statement of the symptoms produced by the plant, the time at which the losses may be expected to occur, and the means, so far as they are known, of avoiding them. It is not intended to give any complete description of the plants or their effects. For this, reference must be made to the more detailed reports upon specific plants. In regard to most of

these our knowledge is at present on a firm basis of experimental proof. It has seemed best, however, to add to the list some plants which undoubtedly produce poisonous effects, but which have never been subjected to detailed experimental study.

### LOCO PLANTS.

Without any doubt the most destructive of all the poisonous plants are those going under the general name of loco. That extensive losses of domestic animals have been caused by loco plants has been claimed for a long time, but it is only within the last few years that exact evidence, by careful experiments, has shown definitely that these plants produce the effect which has been popularly ascribed to them. A great deal of interest attaches to these plants because of their wide distribution and the large number of animals that have been poisoned by them, including cattle, horses, and sheep, and also because of the difficulty of actually proving the existence of a poisonous principle in the plants themselves.

The loco plant has had its place in romantic literature, as it has frequently been claimed that it produces the same effect upon human beings as upon the lower animals, and it has been a popular subject for the short-story writer. None of these stories of "locoed" men, however, has any substantial foundation.

The word loco is from the Spanish, meaning crazy, and was given to the plant because of its supposed effect upon its victims. Loco plants have been heard of in practically all the open-range country of the West, except in the higher mountains, and there is no doubt that under the term loco disease a large number of ailments have been included. Experimental proof, however, has shown that there is a disease occasioned by the loco plants, with distinct symptoms and with a definite outcome.

#### WHITE LOCO (*OXYTROPIS LAMBERTI*).

Of all the loco plants the most destructive is the "white loco," or "rattle-weed," *Oxytropis lamberti* of the botanists. This is not because of its greater toxicity, but because it grows in great abundance over a wide extent of territory and is poisonous not only to cattle and sheep but to horses. It is found in the Plains region east of the Rocky Mountains from Alaska to Mexico. Like all the loco plants, it belongs to the Leguminosæ or pea family, the family in which are found peas, beans, clovers, alfalfas, etc. It is a perennial plant, living two or three years or more, and has a long root system which enables it to withstand conditions of drought. The leaflets of the compound leaves are slender, more or less hairy, and of an olive-green color. Thrifty plants are a foot or more in height.

The spikes of flowers are borne on stems extending above the leaves and are commonly of a prevailing white color, hence its name





WHITE LOCO, OR "RATTLEWEED" (*OXYTROPIS LAMBERTII*).

This is the most destructive of all the loco plants, not because of its greater toxicity but because of its wide distribution, extending from Alaska on the north to Mexico on the south, and from the Continental Divide to the western part of Minnesota. It poisons horses, cattle, and sheep.





FIELD OF OXYTROPIS LAMBERTI.

This landscape, taken in Montana, is a typical one and shows with what great abundance *Oxytropis lamberti*, or white loco, grows under favorable circumstances. It grows in equal abundance in Wyoming and Colorado.







**ASTRAGALUS DRUMMONDI.**

This plant grows very abundantly in the same region as the white loco, and frequently is considered as one of the loco plants. Careful experimental work has proved that this plant is harmless.





of white loco. The corolla, however, is frequently streaked with purple; sometimes the calyx is red; and sometimes, particularly in mountain regions, the whole corolla may be of a deep violet or purple color. All gradations in color may be found between these extremes. When the plants are in fruit the pods rattle as one hits them in walking, very closely imitating the rattle of a rattlesnake, hence the name "rattle-weed."

Plate I is a picture of the white loco as found in the plains of Colorado. Plate II shows a field of the plant in blossom. The latter picture was taken in the Yellowstone Valley of Montana, but it could easily be duplicated in Wyoming or Colorado.

It is evident that where the plant occurs in these great numbers such a thing as eradication is impossible except by plowing over the whole country. If animals are turned loose in such a region as this they certainly will have an opportunity to obtain an abundance of loco.

#### ASTRAGALUS DRUMMONDI.

In Plate III is given a picture of *Astragalus drummondi*, which occurs in many regions in connection with the white loco and is frequently considered a loco plant. The plant is readily recognized by its coarse stems and yellowish flowers, both the flowers and pods being somewhat dependent. Many people consider this a dangerous plant, but extensive experiments by the Department of Agriculture have shown that it is entirely harmless and need not be feared. The picture is given here only that stockmen may be able to recognize it as a plant which need not be avoided.

#### OXYTROPIS BESSEYI.

Plate IV shows a picture of *Oxytropis besseyi*. This is a leguminous plant, rather common in the Yellowstone Valley, which is very closely allied to the white loco and is frequently mistaken for it. The flowers are of a deep-pink color, and the plant, while it grows in the same regions as the white loco, is found upon the arid barren summits of hills, the white loco growing most abundantly at slightly lower levels. The two plants intermingle to some extent, but after a little experience one is able to distinguish between them, as there are certain noticeable differences in the leaves. *Oxytropis besseyi* is known in Montana sometimes as the red loco, because of the color of the flowers. Although the plant is closely related to the white loco and grows in the same regions, there is abundant experimental evidence that it is harmless. It should not be considered as a loco plant. The writer considers that the term "loco" should be applied only to such leguminous plants as have been proved to have poisonous properties.

PURPLE LOCO (*ASTRAGALUS MOLLISSIMUS*).

This plant, popularly known as "purple loco," "woolly loco," and sometimes as "Texas loco," is one that has been historically known as the true loco. It is probably the first plant which was recognized as a loco dangerous to live stock. It does not grow north of Nebraska, and perhaps is most abundant in the Panhandle of Texas, although it is found in adjoining regions of New Mexico, Colorado, Kansas, and Nebraska. The leaflets are very hairy and are much broader than those of the white loco. The plant also has a true stem, while the white loco has sometimes been known as the "stemless loco."

Plate V shows a very small plant of this loco. The flowers are not as conspicuous as in the white loco, and the corolla is of a deep-purple color. The pods are shorter, thicker, and of a deep-brown color. Large plants of purple loco may under favorable circumstances be about a foot in height and perhaps 2 feet in diameter. It does not commonly grow in the great abundance characteristic of the white loco, but there are sometimes fairly extensive fields. Where it grows in connection with the white loco the purple loco is more inclined to grow at the lower levels, while the white loco is found upon the sides of elevations. Purple loco is particularly destructive to horses; cattle may be poisoned by it, too, although this is rarely the case, perhaps because cattle do not eat it very readily.

*ASTRAGALUS DIPHYSUS*.

Plate VI is a picture of *Astragalus diphyus*, which is a type of a number of loco plants growing in the Southwest. These plants differ in their appearance very markedly from the white and purple locoes, but although only a few feeding experiments have been performed, there is every reason to believe that they are fully as destructive as the better known plants. Horses seem more likely to be affected by these plants than cattle, although in the Southwest there are a great many locoed cattle. Closely allied to the plant illustrated are a number of species which there is every reason to consider as true loco plants and which it is incumbent upon stockmen to prevent stock from eating.

## SYMPTOMS OF LOCO POISONING.

All the loco plants produce similar effects. These symptoms appear only after a somewhat prolonged feeding upon the plant, and this fact has led to the failure of a great many feeding experiments with loco. Ordinarily the first symptom in a locoed animal is a loss of condition. This is followed by irregularities of gait and weakness which in many cases seems almost to amount to paralysis. The animal shows a lack of coordination in its muscular movements, due without doubt to the effect of the plant upon the central nervous

system. Horses formerly gentle become uncontrollable and will shy violently at imaginary objects or leap high over some slight obstruction. Generally speaking, a locoed horse can neither be led nor backed, and when put in motion can not easily be stopped or turned, but may continue until it runs against a fence or other obstruction.

Many animals acquire a liking for the plant to such an extent that they will eat nothing else. This, however, is not true in all cases. The animal, when affected, shows progressive emaciation and eventually starves to death. It is not at all unusual in a country where there are locoed cattle to see a steer standing off by itself, sometimes remaining in one position for hours, or even for days, and finally falling and dying without making any attempt to go elsewhere, either for food or water.

The losses from loco plants have been enormous. Some owners have gone into bankruptcy, and in many cases it has been found impossible to run horses or cattle upon certain ranges.

#### TREATMENT OF ANIMALS POISONED BY LOCO.

It does not always follow that animals eat the plants in any very large quantity, for even in a place like that shown in Plate II cattle may be pastured for a long time without any of them becoming affected. The most important point in regard to the handling of domestic animals upon such a loco range, as will be emphasized later in this paper, is to see that they have an abundance of good food. When the range contains in addition to the loco an abundance of grasses the number of locoed animals is very much reduced.

When the first symptoms of loco poisoning are observed, it is essential that the animals be removed to a place where they can not get the plants. Horses are very apt, after becoming slightly locoed, to continue eating the plant until they are absolutely worthless. It is always unsafe to turn a partly locoed horse upon a region that is covered with the plant. The same is true in regard to cattle, only to a lesser degree. As soon as symptoms of loco poisoning are seen in cattle they should be removed from the open range and, if possible, put upon alfalfa pasture. All locoed animals are constipated, and the alfalfa has a tendency to relieve this condition.

Generally speaking, if cattle are moved from the open range in time and fed upon alfalfa, the greater number of them will recover. After recovery it is well to put them upon the market as soon as possible, for if turned out upon the range again there is always a possibility that they may become locoed a second time, with worse results than at first. If the animals are valuable enough to justify the time spent in treating them, their recovery will be hastened, in the case of horses, by daily doses of 15 to 20 c. c. (4 to 6 drams)



of Fowler's solution, while cattle may be given hypodermic injections of strychnin. These doses should be continued for at least a month. Care should be taken in the use of strychnin, as locoed animals are very sensitive to its use. It is better that doses for cattle should not exceed three-twentieths or four-twentieths of a grain. Never, in the case of a large animal, should more than one-half grain be given.

In the case of locoed sheep upon the range, if the number is small, it is not profitable to spend any time or trouble with them. It is better to slaughter them immediately, as a locoed sheep will teach others the same habit. If, however, a number of locoed sheep can be separated and, like the cattle, be turned into an alfalfa field, most of them are likely to recover. Sheep may be helped by doses of one-twentieth grain of strychnin, but ordinarily, on account of the small value of individual animals, it is not profitable to spend the time which is necessary to insure their recovery.

In handling animals in a loco country it should be remembered that all domestic animals are more or less imitative, and loco eaters are likely to teach others to do the same thing. Therefore, so far as possible, all animals that have acquired the habit of loco eating should be separated from the others.

### LARKSPURS.

A great many species of larkspurs grow in the western stock ranges, and they are widely distributed throughout the mountain regions which are used for pasturage. These plants when in blossom are very easily recognized by the peculiar form of the flower. Before blossoming there are a few plants with which they may be confused by a person who is not versed in botany, but it is not particularly difficult for the ordinary observer, after a little experience, to recognize larkspurs in all stages of growth. While there is a large number of species, all may be grouped under the two general heads of tall larkspurs and low larkspurs.

#### TALL LARKSPURS.

The tall larkspurs in their maturity reach a height of 4, or even 6 and 8 feet. They are perennials and grow in great abundance in the high mountain regions, ordinarily preferring damp and sheltered places, such as are found in mountain valleys and under trees. Under some circumstances, however, they may grow in considerable abundance in the open. All the tall larkspurs agree in the form of the leaf, which is well illustrated in Plates VII and VIII. The flowers, with the spur from which the plant gets its name, are very characteristic in their form and in most species vary in their colors through various shades of violet, blue, and purple. Before the plants are mature the leaves may be confused with those of the



OXYTROPIS BESSEYI.

This plant, closely resembling the white loco, grows in the same regions, especially in Montana and Wyoming, in close proximity to the white loco, and is frequently considered a loco plant. Experimental work has proved that it is harmless. It can be distinguished from the white loco by the dark color of the flowers, and by the fact that it is more likely to grow upon the dry summits of the hills, in more sterile locations than those in which the white loco is found.







PURPLE LOCO, OR TEXAS LOCO (*ASTRAGALUS MOLLISSIMUS*).

This plant is sometimes known as the true loco, and grows abundantly in Texas and New Mexico. It seldom injures any animals except horses, but is very poisonous to them.





LOCO PLANT (*ASTRAGALUS DIPHYUS*).

This is a type of a number of loco plants growing in the Southwest, which are particularly destructive to horses. Experimental work has proved that this poisons both horses and cattle.







TALL LARKSPUR (*DELPHINIUM CUCULLATUM*).

This is the tall larkspur which is abundant in Montana and adjoining States. It differs from the other tall larkspurs in the smaller size and less conspicuous coloring of the flowers.







TALL LARKSPUR (*DELPHINIUM TROLLIIFOLIUM*).

This is the tall larkspur of the Northwest, and is conspicuous because of its large and beautiful flowers.





ACONITE (*ACONITUM COLUMBIANUM*).

The aconites grow in close proximity to the tall larkspurs, and are frequently confused with them. The leaves are almost identical in form, and the plants grow to the same height. They can, however, be distinguished by the form and color of the flowers. Although poisonous plants, the aconites do not poison cattle.







TALL LARKSPUR (*DELPHINIUM BARBEVYI*).

In this picture is a clump of this species of tall larkspur. Probably *Delphinium bicolor* is the most widely distributed of the tall larkspurs, and is responsible for greater losses of cattle than any other. It extends from Colorado to the Sierras.





wild geranium, which in many places grows abundantly with the tall larkspur, but the different habit of the plant makes it comparatively easy to distinguish between them.

It is more difficult to distinguish between aconite and larkspur, because the leaves of the aconite are almost identical in form with those of the larkspur, and the habit of the plant is similar. In Plate IX is given a picture of the ordinary aconite in which this similarity will be noted. The leaves of aconite have shorter petioles (leaf stalks) than those of larkspur.

Species of tall larkspurs are found in all the mountain ranges of the West at high elevations, growing up as high as the timber line. Sometimes they are found as scattered clumps of plants, but frequently they grow in large masses.

Plate VII shows the leaf, flower, and seed pod of the tall larkspur which is most common in Montana and adjoining States, known to botanists as *Delphinium cucullatum*. This does not ordinarily grow to any considerable height—perhaps not more than 4 feet—and the flower is less conspicuous than in most of the tall larkspurs. The color is ordinarily described as a grayish purple, due to the fact that there is considerable white in connection with the violet-purple shades of the corolla. This plant is responsible for most of the deaths of cattle by larkspur in Montana. Plate VIII shows the tall larkspur of the Pacific coast region; it has a much more conspicuous and beautiful flower than *Delphinium cucullatum*.

*Delphinium barbeyi* is perhaps the most widely distributed species of the tall larkspurs and is the plant which causes the greater part of the tall-larkspur losses in Colorado, Utah, and some other localities. Plate X shows the plant as it grows in the midst of other plants in the high mountains of Colorado. In this picture it is growing in connection with aconite, *Veratrum*, and some other weeds.

In most cases the tall larkspurs blossom during the summer months and do not die down until they are broken by the snows of the early fall. The exact time of blossoming differs with the species and with the places in which they occur. In the mountains of Colorado the blossoming period is ordinarily in July, and the seeds are formed in August, after which the plant commences to dry up. The leaves of the tall larkspurs lose their poisonous properties after blossoming, so that in most localities the cases of poisoning from these plants occur in the spring or early summer. In the case of some species, however, especially in localities where the snow-fall is heavy and remains late in the season, in certain parts of the Sierras, the period of blossoming continues into the late summer, so that poisoning cases may occur at any time during the season.

The seeds of the tall larkspurs are very poisonous, but they are not eaten to any extent, by cattle.

## ACONITE.

Plate IX is a picture of the ordinary aconite and is inserted in order that it can be compared with the picture of the larkspur. Aconite, as is well known, is a poisonous plant, but somewhat extensive experimental work by the Department of Agriculture seems to have demonstrated that it does not poison live stock upon the range. It is important, therefore, that this plant should be distinguished from larkspur, because in some localities it occurs in great abundance, while larkspur is comparatively rare. This is true of certain parts of the Yellowstone Park, where in some localities the swampy regions are blue with aconite in the summer months, while the larkspur is only rarely met with. In other parts, however, like the region between the Yellowstone Lake and the Grand Canyon, the larkspur is very abundant and the aconite comparatively rare.

Flowers of the aconite have the peculiar form from which the plant has been known as "monkshood," and in most regions they are much darker in color than the larkspurs. Generally speaking, in the aconites of the West the flowers are of a very deep blue. There are localities, however, in which the shades of color are much lighter, almost the exact shades of the violet and purple that are more typical of the larkspurs, while in other places the flowers are almost white.

The roots of the tall larkspur are long, tough, and fibrous, while the roots of aconite are short and tuberlike, with golden-yellow rootlets. The stem of the tall larkspur is hollow, while the stem of the aconite is pithy.

## LOW LARKSPUR.

Plate XI is a typical picture of the low larkspur which is most widely spread throughout the western ranges. This species is *Delphinium menziesii*, probably the most destructive of the low larkspurs, due to the fact that it occurs in such enormous masses. There are regions in Colorado and Utah where many acres are almost carpeted with these plants. They occur early in the spring, immediately after the snow disappears, growing more rapidly than the grasses, so that in some regions they seem for the time almost to preempt the soil. These low larkspurs blossom comparatively early in the season, and in Colorado *Delphinium menziesii* dries up and disappears not far from the 1st of July. Consequently the cases of poisoning from low larkspurs occur almost entirely in the months of May and June.

It will be noted that the leaves of the low larkspurs are quite different from those of the tall larkspurs, but are easily recognized after one becomes fairly familiar with them.

There is another low larkspur, occurring quite commonly in Montana, the *Delphinium bicolor*, which is typical of somewhat lower

altitudes than *Delphinium menziesii* and apparently never grows in sufficiently large masses to be dangerous.

The low larkspurs are poisonous throughout the whole period of their lives, while the tall larkspurs gradually lose their poisonous properties after blossoming.

In Plate XII is shown a larkspur with white blossoms, *Delphinium virescens*, which is quite common in the plains regions east of the Rocky Mountains. This plant probably rarely occurs in sufficient abundance to cause harm, but there is reason to think that at some seasons it has occasioned the death of a considerable number of animals.

#### PARTS OF LARKSPURS POISONOUS.

There is a general belief throughout the West that it is the roots of the larkspur which are particularly poisonous. Experiments have proved conclusively, however, that the different parts of the plant are equally poisonous, with the exception that the seeds are especially so. Probably in almost all cases of larkspur poisoning the trouble is caused by eating the leaves, sometimes with the flowers. As was intimated before, most of the cases of larkspur poisoning occur in the spring or early summer.

#### ANIMALS POISONED BY THE LARKSPURS.

While horses can be poisoned by corral feeding of larkspurs, there is reason to think that if left to themselves upon the range they never eat enough of these plants to do any harm. Sheep eat the larkspurs freely without suffering any evil consequences. There is quite a general belief in many regions of the West that losses of sheep have been caused by larkspur feeding, but extensive experiments upon a large number of species, and in different regions, have proved conclusively that sheep can be grazed upon larkspur without any risk whatever. In fact, it may almost be said that larkspur furnishes good forage for sheep. The losses from larkspur poisoning, then, are altogether with cattle, and these losses are very heavy.

#### SYMPTOMS OF LARKSPUR POISONING.

While the result of corral feeding shows that there are a number of preliminary symptoms, as animals are noticed upon the range the first symptom commonly observed is the sudden falling of the animal, accompanied by violent struggles. The animal is unable to rise, but after a few moments may get upon its feet and walk away, and show no further symptoms. In more acute cases of poisoning the first fall will be followed by a second, and that possibly by a succession of falls, which in severe cases of poisoning are followed by complete prostration, vomiting, and death.



## TREATMENT OF CATTLE POISONED BY LARKSPUR.

Inasmuch as death from larkspur poisoning is caused by respiratory paralysis, it is very important, if the animal is found poisoned by this plant, that immediate means shall be taken to relieve the difficulty in respiration. In their struggles animals poisoned by larkspur ordinarily throw themselves with their heads downhill, and in this position the stomach and intestines press upon the lungs and seriously interfere with the function of respiration. If while in this position the animal should vomit, some of the regurgitated material is very apt to fall back into the windpipe and cause asphyxiation. When, therefore, an animal is seen to fall from larkspur poisoning, it should be turned about with its head uphill and erect and should then be left undisturbed. It is also desirable under such conditions to give the physostigmin remedy hypodermically, as recommended in Farmers' Bulletin 531. The remedy has the following formula:

|                              |                      |
|------------------------------|----------------------|
| Physostigmin salicylate..... | 1 grain.             |
| Pilocarpin hydrochlorid..... | 2 grains.            |
| Strychnin sulphate.....      | $\frac{1}{2}$ grain. |

This formula would apply to an animal weighing 500 or 600 pounds. For a large steer or cow of 1,000 pounds or more the dose should be twice that given in the formula. These materials can be obtained from any dealer in drugs. The physostigmin salicylate and pilocarpin hydrochlorid are furnished in veterinary hypodermic tablets, each containing one-half grain of physostigmin salicylate and 1 grain of pilocarpin hydrochlorid. The strychnin sulphate can be obtained in tablets each containing one-half grain. These dissolve easily, and it is well to have two or three doses ready in small homeopathic bottles. For yearlings one should use two of the physostigmin-pilocarpin tablets and one of the half-grain strychnin tablets dissolved in enough water to fill an 8-dram homeopathic bottle; for full-grown cattle four of the physostigmin-pilocarpin tablets and two of the strychnin tablets dissolved in an 8-dram bottle full of water should be used.

It is best to use an all-metal hypodermic syringe. This can be easily cleaned by boiling. The form which has been found most useful for the field is that known as the Quitman syringe. In this the needles are carried in the hollow piston, and a case is therefore unnecessary. The syringe should be of the 10-centimeter size, which holds half an 8-dram bottle of water, so that the remedy can be given to yearlings in a single dose, while for mature cattle the syringe must be filled twice. The needle is most conveniently inserted in the shoulder. There is little doubt that prompt treatment of animals poisoned by larkspur will result in the saving of most of the cases.



LOW LARKSPUR (*DELPHINIUM MENZIESII*).

This is the most common of the low larkspurs, extending from Colorado to the Sierras, and causes heavy losses of cattle.







**PRAIRIE LARKSPUR (*DELPHINIUM VIRESCENS*).**

The white larkspur of the plains, which is found as far south as Texas. It is probably responsible for occasional losses of cattle in those regions.



**CICUTA (WATER HEMLOCK).**

The most poisonous of all the plants in the United States is, without any doubt, the *Cicuta*, which is most commonly known throughout the West as "parsnip"; sometimes as "water hemlock." There are several species of *Cicuta* recognized by our botanists, but they are very closely allied, and for the purpose of stockmen the description of one will serve for all. Plates XIII and XIV are of the *Cicuta*, which is common on the Pacific slope.

*Cicuta* is an umbelliferous plant growing in swamps and damp valleys and frequently very abundantly along irrigating ditches. A large number of umbelliferous plants occur in these localities, and it is difficult for the nonbotanical person to distinguish *Cicuta* from other similar nonpoisonous plants. Probably the easiest way to distinguish the plant is by an examination of the rootstock. The *Cicuta* grows from a rootstock to which are attached roots which may be small, as shown in Plate XIV, or may take the form of a group of thick, fleshy tubers. In longitudinal section this rootstock shows more or less distinctly a number of transverse chambers, as shown in Plate XIV. By this peculiarity of structure *Cicuta* can be distinguished from most plants growing in places where it is likely to be found.

**POISONING BY CICUTA.**

It has been commonly thought that the tops of *Cicuta* when found in hay caused the loss of stock, but experimental work of the department has shown quite conclusively that the tops and seeds never occasion losses. The rootstock, however, is violently poisonous, and a very small quantity of this is sufficient to kill any animal that eats it. Probably all animals are susceptible to the effects of this plant. The losses of domestic animals are mainly of cattle, which either obtain the rootstocks that have been plowed up along irrigating ditches or find them along watercourses in mountain valleys where they have been washed out by the high water.

**SYMPTOMS, TREATMENT, AND LOSSES.**

The symptoms of *Cicuta* poisoning are frothing at the mouth and most violent convulsions, which in a short time ordinarily end in death.

When cattle are severely poisoned the convulsions are so violent that it is almost impossible to administer a remedy; in fact, no effective remedy is known, and death is almost certain to follow cases of severe poisoning by this plant. It frequently happens that human beings, especially children, are poisoned by *Cicuta*, in which case if an emetic can be given promptly, so that the stomach is quickly emptied, recovery usually takes place. Because of the fact that ruminant animals can not empty the stomach by vomiting, this remedy can not be applied to them.



The losses from *Cicuta* poisoning are not ordinarily very heavy, but individual stockmen occasionally lose quite a number of animals.

#### DEATH CAMAS (ZYGADENUS).

The larger part of the losses of sheep from poisonous plants during the spring and early summer months is due to the various species of *Zygadenus*, or death camas.

Plate XV, a picture of *Zygadenus venenosus*, gives a clear idea of the general appearance of these plants. This species is common in the foothill regions of the range country of the West and sometimes occurs in great abundance. It starts early in the spring, before the grasses, and matures during the months of May and June. By reason of its green, grasslike leaves it is not easily recognized in the early stages of its growth. When fully grown it is somewhat conspicuous on account of its yellowish-green flowers, which make it a plant easily distinguished from others. This is especially true when it is growing in quantity, for acres may be covered with these rather striking blossoms.

#### ZYGADENUS ELEGANS.

Another species, *Zygadenus elegans*, resembling the *venenosus* in its general characteristics, is found at higher elevations in the mountains, and grows in a similar way, but is somewhat later in maturing.

#### ZYGADENUS PANICULATUS.

*Zygadenus paniculatus*, of the States farther west, a picture of which is given in Plate XVI, resembles very closely the *venenosus* and *elegans*, but differs mainly in the more extended panicle of flowers. The illustration also shows the seed pods of *Zygadenus*.

These plants are found in practically all the grazing States of the West, and, unfortunately, in many regions they have not been recognized as injurious. In the Northwest, where recognized, the popular term "lobelia" has been applied to *Zygadenus*. Sometimes it is known as "poison sego."

#### SYMPTOMS OF ZYGADENUS POISONING.

The prominent symptoms of *Zygadenus* poisoning, as seen upon the range, are frothing at the mouth, nausea accompanied by vomiting, great weakness accompanied sometimes with nervousness and resulting in collapse of the animal, which may lie without food for hours, or even days, before death terminates the case. It is not unusual for large numbers of sheep in a band to be poisoned by *Zygadenus*, and in such case the result is almost always heavy losses. Perhaps more cases of *Zygadenus* poisoning have been reported from Montana than from other States, but this is simply because the cases have been under observation in that locality; the losses are probably just as heavy in Utah, California, and elsewhere.

## TREATMENT FOR ZYGADENUS POISONING.

There are no medicinal remedies which can be used effectively for *Zygadenus* poisoning. The important thing is to avoid the possibility of the sheep eating any large quantity of the plant. Unfortunately, the plant is quite toxic, so that comparatively small quantities may produce harm.

## LUPINES.

The lupines are among the most conspicuous of the flowering plants upon mountain ranges. They are scattered in a very large number of species practically over all the grazing regions. They are known under a great variety of common names, among which are "blue pea" and "wild bean."

The picture of *Lupinus sericeus*, Plate XVII, will serve for the identification of any of the lupines. The form of the leaf and the color of the flower, ordinarily shades of purple or blue, readily distinguish this plant from others growing in the same neighborhood. The seeds are especially poisonous, and most cases of poisoning result from eating the pods containing seeds. The pods alone, however, may poison, and sometimes sheep are poisoned by the leaves, or by the leaves in combination with the seed pods.

The losses from lupine poisoning are mostly of sheep, although some horses are poisoned. It is probable that the lupines are the principal cause of sheep losses in the late summer and fall months. It is not by any means to be understood that sheep are always poisoned when they come upon a patch of lupine, for bands of sheep may feed through lupine for a whole season without any harm. When, however, a hungry band comes upon a patch of lupine at the time when the pods are filled with seeds, poisoning frequently occurs. Cases of poisoning sometimes happen when sheep are taken from the cars and allowed to graze freely upon lupine. Many cases of poisoning have occurred when the sheep are brought down from the mountains in the fall. If during that passage the band is overtaken by a snowstorm, sometimes it will feed freely upon the lupine pods which remain above the snow, and heavy losses may occur. It is not unusual for several hundred out of a band to be killed by lupine poisoning. These losses are not confined to any one State, but occur in practically all the Western States where sheep are grazed upon the range.

## SYMPTOMS OF LUPINE POISONING.

The symptoms of lupine poisoning resemble in many respects those produced by some other poisonous plants. There is frothing at the mouth, but in addition the animals run about in a frenzy, butting against any opposing object in a way which seems to be characteristic of this disease.

## TREATMENT FOR LUPINE POISONING.

No medicinal remedies have been found for cases of lupine poisoning. The only thing for a sheep herder to do is to make certain in advance that the animals under his care shall not come upon a patch of lupine in pod at a time when they are particularly hungry.

## LAURELS.

Among the plants classed as laurels are a number which are important as poisonous plants and occasion heavy losses, more especially of sheep. All these plants contain a poisonous substance known as andromedotoxin. The following brief statements concern the laurels which are known to cause losses on the western ranges.

## MENZIESIA GLABELLA.

This shrub, which grows in the mountains of the extreme Northwest, has been found to be distinctly poisonous to sheep. It is not known that many losses have occurred from eating this plant, but it was demonstrated in one case in Idaho that the plant was the cause of very heavy losses, and there is no doubt that when sheep in those regions are pastured on the north slopes where *Menziesia* is more likely to grow, and are short of other food, disastrous results may follow. Plate XVIII shows this plant in flower.

BLACK LAUREL (*LEUCOTHOE DAVISIAE*).

This plant, generally known through the Sierras as "black laurel," is particularly destructive to sheep. It has thick, dark-green, oval leaves and small white flowers in erect racemes, as shown in Plate XIX, and grows to a height of about 3 or 4 feet. It is found in small patches at elevations from about 3,500 to 5,000 feet in the northern Sierras in California. While far from common, it is yet a very important plant because of its extremely toxic character. It has been stated that a single leaf will poison a sheep. This statement is probably exaggerated, but experimental work shows that very small quantities will poison sheep and that death may be produced by between one and two ounces.

## LEDUM GLANDULOSUM.

This plant, illustrated in Plate XX, is also known in California as black laurel and probably is not generally distinguished from *Leucothoe davisiae* by the sheepmen, although it has a very different habit. It is rather widely distributed, being found not only in the Sierras and Coast Ranges in California, but also in Oregon, Washington, Nevada, and the Rocky Mountains. While no experimental work has been done with this plant, there seems to be no question that it causes serious losses of sheep in California.





CICUTA VAGANS.

The species of *Cicuta* growing in the northwestern United States. *Cicuta*, commonly known to stockmen as parsnip, is the most poisonous of all our native plants, and grows in damp valleys and along irrigating ditches.





*CICUTA VAGANS.*

A young plant with the rootstock, and a longitudinal section of the rootstock. By the transverse chambers shown in the longitudinal section of the rootstock the *Cicuta* can readily be distinguished from any other plant growing in the same locality.







DEATH CAMAS (*ZYGADENUS VENENOSUS*).

This species of death camas, growing in the foothills, causes heavy losses of sheep during the spring season.







DEATH CAMAS (*ZYGADENUS PANICULATUS*).

This plant has the same properties as *Zygadenus venenosus*, and within its range is equally destructive. It is to be noted that the seeds of the species of *Zygadenus* are especially poisonous.





LUPINE (*LUPINUS SERICEUS*).

All the species of Lupine are supposed to be poisonous, and are the cause of the larger part of the heavy losses of sheep during the late summer and fall months. Sheep are most likely to be poisoned by eating the pods and seeds.







MENZIESIA GLABELLA.

One of the laurels growing in northwestern United States, which has been known to occasion heavy losses of sheep.



BLACK LAUREL (*LEUCOTHOE DAVISIAE*).

This is one of the black laurels, and causes heavy losses of sheep in the Sierras.





BLACK LAUREL (*LEDUM GLANDULOSUM*).

One of the black laurels which, together with *Leucothoe*, cause probably the major part of the losses of sheep in the Sierras.





WHITE LAUREL (*AZALEA OCCIDENTALIS*).

It grows at a lower elevation than the black laurels, and causes heavy losses of sheep in the Sierras.







*RHODODENDRON ALBIFLORUM.*

A laurel causing losses of sheep in the Northwest.



COMMON FERN (*PTERIS AQUILINA*).

The common fern, particularly in the regions of the Northwest, sometimes causes losses of horses and cattle.

## WHITE LAUREL.

White laurel (*Azalea occidentalis*) is illustrated in Plate XXI. It is found in the Coast Ranges and the Sierras, growing at a slightly lower level than the black laurels, and causes considerable losses of sheep.

## RHODODENDRON ALBIFLORUM.

*Rhododendron albiflorum*, illustrated in Plate XXII, is common in the mountains of the Northwest and has undoubtedly caused some losses, although it is not very generally recognized as a poisonous plant. Preliminary experiments apparently show that it is more poisonous than *Menziesia*, but less so than the black laurels.

## SYMPTOMS OF LAUREL POISONING.

The symptoms are practically the same in all cases of laurel poisoning. There is salivation resulting in frothing at the mouth, nausea ordinarily accompanied by vomiting, depression, weakness shown by a staggering gait or inability to stand, and irregular respiration. Grinding of the teeth is frequently noticed in sick animals.

## TREATMENT OF LAUREL POISONING.

Little can be done in the way of remedial treatment. Anything that will aid in elimination will be of some benefit, and to this end purgatives may be given, such as Epsom salt in doses of 4 ounces. The main reliance, however, must be placed on prevention. Herders should learn to recognize and avoid the plants.

## FERN.

The common bracken fern, *Pteris aquilina*, which is illustrated in Plate XXIII, should be mentioned here as one of the poisonous plants, although the losses from it are probably not large. It has long been known abroad that the fern is poisonous to cattle and horses. There have been comparatively few reports in this country of such losses, and those are largely confined to the Northwest. There is no doubt that ferns will poison both cattle and horses, and probably sheep, and care should be taken that hungry animals shall not have an opportunity to consume any large quantity.

## WILD CHERRY.

For years there have been persistent reports of poisoning, especially of sheep, from eating wild-cherry leaves. There has been great difficulty in proving the truth of these stories, for it has frequently happened that of several bands going through a mass of wild cherry, possibly only one would suffer, while the others would go through in an entirely safe manner. A large number of experiments have been

performed with wild-cherry leaves, many of which have been without results. Investigations by the department, however, have proved beyond question that the leaves of wild cherry are extremely poisonous, and there seems to be no doubt that, under certain circumstances, animals may be killed by eating this plant. These cases ordinarily occur along drives that are bordered by wild cherry and where there is very little else for the animals to eat.

Sheepmen should by all means avoid, if possible, trails that are lined with wild cherry, and if it is necessary to drive over these trails, they should take great care that the animals are well supplied with food before commencing the drive. Poisoning from wild cherry is due to prussic acid, and death results very quickly. No treatment is likely to modify the results. Plate XXIV shows one of the wild cherries of the West.

#### MILKWEED (*ASCLEPIAS*).

There are persistent accounts in certain regions of losses, particularly of sheep, by eating milkweed. There seems to be no question of the accuracy of these accounts, although it has been impossible thus far to verify the poisonous properties of milkweed by corral experiments.

The plant is very distasteful to animals under ordinary conditions, and where animals are confined in corrals it is almost impossible to make them eat it. It seems to be true, however, that range animals, when compelled by severe hunger, will sometimes eat enough to occasion disastrous results. Plate XXV shows a picture of the common milkweed.

#### WOODY ASTER (*XYLORRHIZA PARREYI*).

The woody aster, shown in Plate XXVI, occurs in great abundance in certain regions in Wyoming, and has been accused of causing losses of sheep in those localities. There appears to be no doubt that the plant is poisonous. It is a fibrous plant, however, and is very distasteful to sheep under ordinary circumstances, so there is very little danger from it, provided the sheep are kept in a region where sufficient feed is obtainable.

#### COLORADO RUBBER PLANT, OR PINGUE (*HYMENOXYS FLORIBUNDA*).

This plant, shown in Plate XXVII, is confined to the northern part of New Mexico and the southern part of Colorado and Utah, and in certain localities grows in very great abundance. Its aster-like flowers are quite conspicuous, and the plant is readily distinguished from other similar plants because of the dark golden-yellow color of the flowers. The rubber plant has had a good deal of advertising because it contains a certain amount of rubber and has been the



subject of commercial exploitation. It is claimed, especially in southern Colorado and northern New Mexico, that sheep feeding upon this plant in the late winter suffer severely.

Experimental work has proved that the plant is poisonous to sheep, but it has been found difficult, under corral conditions, to make them eat it. Field observations have shown that in the localities where animals are reported to have suffered, the sheep in the latter part of the winter are frequently kept under conditions closely approaching starvation, and at such times doubtless, by force of circumstances, they would eat more of the plant. It is very much to be doubted if there would be any losses from this plant if bands were properly fed.

#### WESTERN SNEEZEWEED (*DUGALDIA HOOPESII*).

Western sneezeweed, sometimes called "yellow weed" by the stockmen, is found in great abundance on the sheep ranges of the Wasatch mountains in Utah, especially in localities where the range has been heavily grazed. The plant is distributed in greater or less numbers from Wyoming in the North to New Mexico and Arizona in the South, and as far west as California, but it is in Utah that it has become prominent as a poisonous plant.

The plant, shown in Plates XXVIII and XXIX, is a stout perennial composite, growing to 2 or 3 feet in height, with thick deep-green leaves. The rays of the flower are of an orange color and the disk a brownish orange; the blossoming period in the Wasatch mountains ends the middle or last of August. Its range in elevation is from 7,000 to 10,500 feet.

Under ordinary range conditions the western sneezeweed seems to be dangerous only to sheep. It has been found to be the cause of what is known in Utah as the "spewing sickness" of sheep, from which there have been quite heavy losses.

#### SYMPTOMS OF POISONING BY *DUGALDIA*.

The marked symptoms of *Dugaldia* poisoning are depression, weakness, salivation, and nausea accompanied with vomiting; this latter symptom is so prominent as to have given the disease its popular name. Diarrhea is common, and bloating is a prominent symptom in the animals poisoned on the range. The poison is cumulative, and its effects continue for a long time.

#### TREATMENT FOR *DUGALDIA* POISONING.

No medicinal remedy for the disease has been found. It is the custom of sheepmen on the Wasatch mountains, when their sheep are found to be "spewing," to take them to lower altitudes on "browse range," when their condition is improved. It is recognized,

however, that this treatment does not bring about a real cure. It is important that herders should recognize the plant and so far as possible avoid ranges or parts of ranges where it is especially abundant. Generally speaking, when a band of sheep is found to be suffering from this plant it is because they have been eating it for some time, and perhaps a single large feeding may have precipitated the trouble, which is mainly due to the accumulated effect of prolonged feeding.

### OAK.

Throughout the grazing regions of the West there is a very general belief in the poisonous properties of oak leaves, more particularly in regard to their supposed toxic properties for cattle. It is quite generally thought that poisonous effects are produced in the spring when cattle are eating the buds and young leaves. This belief applies especially to the Gambel oak (*Quercus gambellii*), which is a common scrub oak of Colorado, Utah, and New Mexico, and to the shinnery oak (*Quercus havardi*), a low shrub in eastern New Mexico and western Texas. Extended experiments are being carried out upon these plants by the U. S. Department of Agriculture. These experiments are still in progress, and the results can not be considered as definitely conclusive. It seems probable, however, that oak leaves do not have any distinctly poisonous properties, but, on the contrary, especially when the leaves are mature, form a valuable element in the forage of range animals. When cattle are fed exclusively on oak leaves they suffer from constipation, so that on an overgrazed range this condition may become so serious as to produce illness and death. No serious results need be expected, however, provided the forage is sufficiently abundant so that there is enough variety to preclude the exclusive use of oak.

### PSORALEA TENUIFOLIA.

This is a very common plant on the plains of Colorado, Wyoming, and Montana, and is found as far east as Illinois. There have been many reports of its poisonous effects on horses and cattle, and it is said to have been used by the Indians for poisoning fish. Several species of *Psoralea* have been examined by chemists, and have been found to contain poisonous principles. One of the species has been popularly known as a loco weed. There has been no experimental work to prove its effect on domestic animals, and as it is distasteful to grazing animals it can not, under any circumstances, be considered an important poisonous plant. There is good reason, however, to suspect it of sometimes being harmful, if animals are forced to eat it by reason of poor pasturage or because it is present in large quantity in hay. Plate XXX is a picture of this plant.



WILD CHERRY (*PRUNUS NANA*).

The wild cherries grow in great abundance upon the stock ranges of the mountain regions and sometimes occasion quite heavy losses.







COMMON MILKWEED (*ASCLEPIAS SPECIOSA*).

While there is little experimental evidence against the milkweeds, there seems to be no doubt that occasionally sheep, through lack of better forage, eat considerable quantities of milkweed with fatal results.



WOODY ASTER (*XYLORRHIZA PARREYI*).

The woody aster has been considered to cause losses of sheep in Wyoming. It is probable that sheep eat it only when there is a lack of other forage.



COLORADO RUBBER PLANT OR PINGUE (*HYMENOXYS FLORIBUNDA*).

For a long time the Colorado rubber plant has been accused of causing losses of sheep in northern New Mexico and southern Colorado.



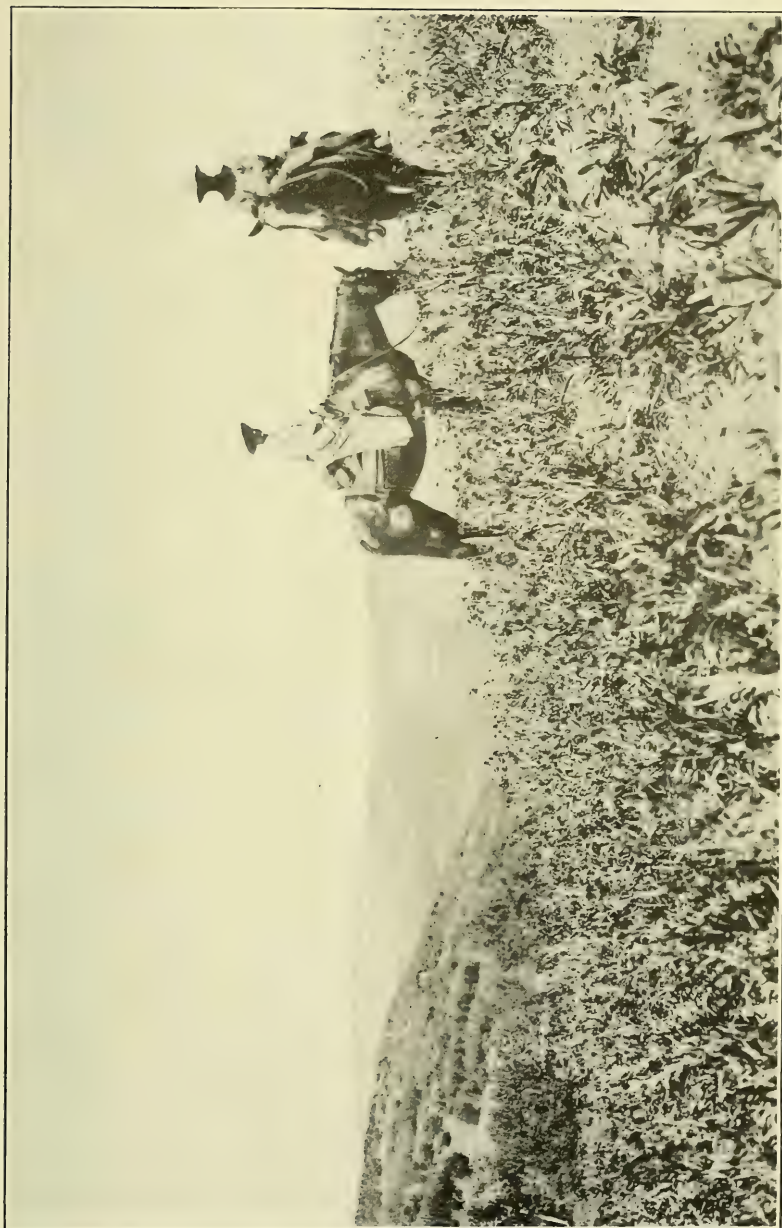




WESTERN SNEEZEWEED (*DUGALDIA HOOPESII*).

This, especially in Utah, causes serious losses of sheep.





WESTERN SNEEZEWEED (*DUGALDIA HOOPESII*).

This shows how thickly it grows where land is heavily grazed.



*PSORALEA TENUIFLORA.*

A very common plant on the plains, supposed to be poisonous under some circumstances.



## PREVENTION OF LOSSES.

In Farmers' Bulletins 536 and 720 attention was directed to the fact that most of the losses from poisonous plants occur at times when the animals are short of feed, and it was suggested that the larger part of the stock poisoning is indirectly due to scarcity of proper forage. This fact of the intimate relation of scarcity of feed to stock poisoning can not be too strongly impressed upon the people who handle range animals in the West.

There is apparently a popular idea that range animals will voluntarily seek out poisonous plants and eat them by preference. It may be stated as a general fact that this is not true. Animals seldom eat poisonous plants except as they are driven to do so by lack of other food. Almost all poisonous plants are actually distasteful to live stock and under ordinary circumstances will be avoided. The only exception to this, perhaps, is the group of loco plants. Animals do frequently acquire a taste for loco and under some circumstances will eat nothing else, even in the presence of other forage; and yet the initial feeding in the case of loco plants is almost invariably brought about by scarcity of food.

It has long been known that loco eating is ordinarily commenced in the winter season or in the early spring when the loco plants are green and luscious, and before the grass has started. The loco plants at that time are the most prominent plants on the plains, and animals commence to eat them because of lack of other food. Many animals after feeding upon loco a short time acquire a liking for it and will continue to eat it even in the presence of an abundance of other food. This is not true, however, even of all loco-eating animals, for there are very many which, after the grass has started, will leave the loco and will recover entirely from the effects which have been produced by the preceding feeding.

In the matter of the other plants, the relation between starvation and the eating of the poisonous plant is still more marked. For instance, the larkspurs spring up immediately after the snow leaves the mountains and grow much more rapidly than the surrounding grasses, and if cattle are allowed to go up to the upper ranges before the grasses have had a fair start, they find already occupying the ground the succulent larkspur plants in huge numbers. Sometimes the cattle come from dry winter feed and are anxious to gorge themselves with any green material they find. Under such circumstances if they come upon a field of larkspur they frequently eat enough to produce fatal consequences. Later in the season there is very much less danger from larkspur because of the abundance of other food. If, however, cattle are driven from one range to another and the trail passes through a mass of tall larkspur, it is not

at all unusual for the hungry animals to grab hastily at the plants, and this may result in disastrous consequences. Under such circumstances it is important that the cattle shall not be driven rapidly, for then they will snatch all the more, and they should also have been thoroughly fed before going upon such a drive.

This has been illustrated in certain places in Colorado, where it is customary to drive cattle from one range to another, and for years there were always heavy losses. In the old days it was the custom to gather the cattle together and rush them as rapidly as possible through the place where the tall larkspur was growing. Losses invariably occurred. In recent years, instead of gathering the cattle together they have been put through the drive in small numbers and have been allowed to feed before starting. They are not driven rapidly. Under such conditions no losses have occurred.

It is also evident, from what has been said earlier in this paper, that if cattle can be kept off fields of larkspur until after the plant has blossomed, little trouble may be expected. This method has been employed for many years in certain regions in Colorado, where it is a common practice to "ride for poison," as it is called; that is, the herders ride and keep the cattle down from the higher ranges until the larkspur has blossomed and matured, after which there is no further danger. The same thing has been accomplished in certain regions by putting up drift fences which are designed to keep the cattle on the lower ranges until the danger is past. There are valleys known as death traps for cattle. Frequently it will be found that in these valleys the tall larkspur is thriving in large clumps, and cattle drifting in will feed freely upon it. It is often possible under such conditions to clear out this larkspur, or enough of it so there will be no danger. In order to kill the plants, the roots of most of the species should be cut off at least 6 or 8 inches below the surface.

Deaths from *Cicuta* poisoning rarely occur except in the case of animals that are almost in a starving condition. If very hungry animals are turned loose upon a range, and they find a number of *Cicuta* roots lying beside a ditch or along a mountain stream, and there is nothing else to eat, they eat these roots, of course, and death follows.

The losses of sheep from death camas (*Zygadenus*) occur under very similar conditions to those of cattle from larkspur. *Zygadenus* grows very early in the spring. It precedes the grasses in its growth and is present in a succulent condition at a time when other forage is extremely scarce. Inasmuch as it occurs frequently in large masses, if sheep are trailed over these places they are liable to get enough to cause heavy losses. It is particularly important in the handling of sheep in such localities that, if possible, they be grazed in loose order. In fact, this applies to the handling of sheep under all circumstances. When the animals are massed together they will

eat everything in their course, and, because of jealousy, will take particular pains to get every available plant. If, on the other hand, they are kept in loose order and spread widely over the range, they are much less likely to eat any poisonous plant.

This applies equally well to lupine poisoning. When sheep are allowed to feed freely upon a lupine patch and are moved without any haste, no harmful results will occur. If, however, they are massed together and driven in close formation over such a patch, they are almost certain to be poisoned if the plants are in pod at the time. A large number of specific instances have been noted. At one place in Idaho, for instance, where losses have occurred repeatedly, it was found that the sheep were trailed in a narrow space through a patch of lupine. The remedy in such cases clearly is to see that the sheep, when it is necessary to trail them through a patch of lupine, are drifted rather than driven, and that they are well fed when they come upon this locality. It seems probable that intelligent handling of bands of sheep may reduce to almost nothing the losses occasioned by *Zygadenus* and lupine. If, however, hungry sheep come in contact with fields of *Zygadenus* in the spring, or with fields of lupine in the late summer and fall, at a time when the plants are bearing pods, fatal results must be expected.

In one locality in Oregon an instance of this character occurred in the summer of 1914, when something like 4,000 sheep which had been driven rather rapidly along a trail where forage was scarce were turned into a 10-acre pasture on which there was little but sagebrush and lupine, the lupine at that time being in pod. About 400 out of the 4,000 sheep died. Similar instances might be cited in a large number of places. Sometimes successive bands of sheep are driven over a trail, several going without any loss whatever; then one band may suffer heavily, while others following are not harmed. The explanation of these cases seems to be that the first animals going over the trail avail themselves of all the useful forage. The succeeding animals, finding nothing suitable for food, take the poisonous plants, which may be wild cherry or lupine, or, in the case of cattle, larkspur. The animals which are poisoned may exhaust the supply, even of the poisonous plants, so that succeeding bands are not poisoned and get across the trail safely provided they do not fall from actual starvation.

It follows from these facts that it is very undesirable to keep sheep for any length of time upon the same bedding ground. This has been shown to be bad for the range on general principles, but it is also rather risky for the sheep themselves, for if animals go out from the same place day after day and return at night they will eat everything that is available along the route. In such cases, if there are poisonous plants to be obtained, the animals are pretty apt at some



time to get hold of them, with disastrous results. This has been very clearly shown in a case of *Menziesia* (laurel) poisoning, in which animals were bedded on a forest range for five nights in the same place; the animals were safe for the first two nights, but after that there was heavy loss. At the same time a band that was wandering about without a herder in the same region was uninjured.

It can not be too strongly impressed upon persons handling sheep upon the range that the sheep should be allowed to graze as far as possible under strictly natural conditions. By this is meant that they should be allowed to go freely, separated from each other, moving slowly, and not allowed to graze over and over upon the same ground. The so-called blanket system of herding, which is advocated by the Forest Service, in addition to the fact that it aids in the conservation of the range, will also without any doubt reduce the losses from poisonous plants to a minimum, if it does not entirely do away with them.

#### CONCLUSION.

In conclusion, it should be stated that, generally speaking, very little must be expected from medicinal remedies to reduce the losses from poisonous plants. It is true that such remedies will help in the case of locoed animals and will save life in the case of larkspur poisoning of cattle. Generally speaking, however, the reliance should be placed not in remedies, but upon prevention. Animals must be so well cared for that they will not wish to eat poisonous plants. Something may be done in the way of eradication, as was indicated under the discussion of larkspur. Larkspur can doubtless be eradicated within a limited area. The locoes in pastures can be eradicated with very little difficulty, but upon the open range dependence must be placed upon avoidance rather than eradication. *Zygadenus*, too, does its harm upon the open range, and there it occurs in such large masses that eradication is impossible. In the matter of *Cicuta*, farmers might, without doubt, accomplish much by digging it up along their irrigation ditches, and this practice is usual in a great many localities. But in the main the losses from poisonous plants must be prevented by careful handling of the herds, remembering always that animals are not likely to eat poisonous plants by preference, but that under starvation conditions they may be driven to the use of such material for forage with most disastrous results.





UNITED STATES DEPARTMENT OF AGRICULTURE  
BULLETIN No. 555

Contribution from the Office of Public Roads and Rural Engineering  
LOGAN WALLER PAGE, Director

Washington, D. C.



November 26, 1917

STANDARD FORMS FOR  
SPECIFICATIONS, TESTS, REPORTS, AND  
METHODS OF SAMPLING FOR  
ROAD MATERIALS

As recommended by the  
FIRST CONFERENCE OF STATE HIGHWAY TESTING ENGINEERS  
AND CHEMISTS

Washington, D. C., February 12 to 17, 1917

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UNITED STATES DEPARTMENT OF AGRICULTURE  
BULLETIN No. 556

Contribution from the Forest Service  
HENRY S. GRAVES, Forester

Washington, D. C.

PROFESSIONAL PAPER

September 15, 1917

MECHANICAL PROPERTIES OF WOODS  
GROWN IN THE UNITED STATES

By

J. A. NEWLIN, in Charge of Timber Tests  
and THOMAS R. C. WILSON, Engineer in  
Forest Products

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UNITED STATES DEPARTMENT OF AGRICULTURE  
BULLETIN No. 558

Contribution from the Office of Markets and Rural Organization  
CHARLES J. BRAND, Chief

Washington, D. C.



July 28, 1917

MARKETING GRAIN AT COUNTRY POINTS

By

GEORGE LIVINGSTON and K. B. SEEDS,  
Specialists in Grain Marketing

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GOVERNMENT PRINTING OFFICE  
1917



UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 559

Contribution from the Office of Markets and Rural Organization  
CHARLES J. BRAND, Chief

Washington, D. C.



July 14, 1917

ACCOUNTING RECORDS FOR COUNTRY  
CREAMERIES

By

JOHN R. HUMPHREY, Investigator in Market Business  
Practice, and G. A. NAHSTOLL, Assistant in Market  
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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 564

Contribution from the Bureau of Entomology  
L. O. HOWARD, Chief

Washington, D. C.

October 4, 1917

COLLECTION OF WEEVILS AND  
INFESTED SQUARES AS A MEANS OF CONTROL  
OF THE COTTON BOLL WEEVIL IN  
THE MISSISSIPPI DELTA

By

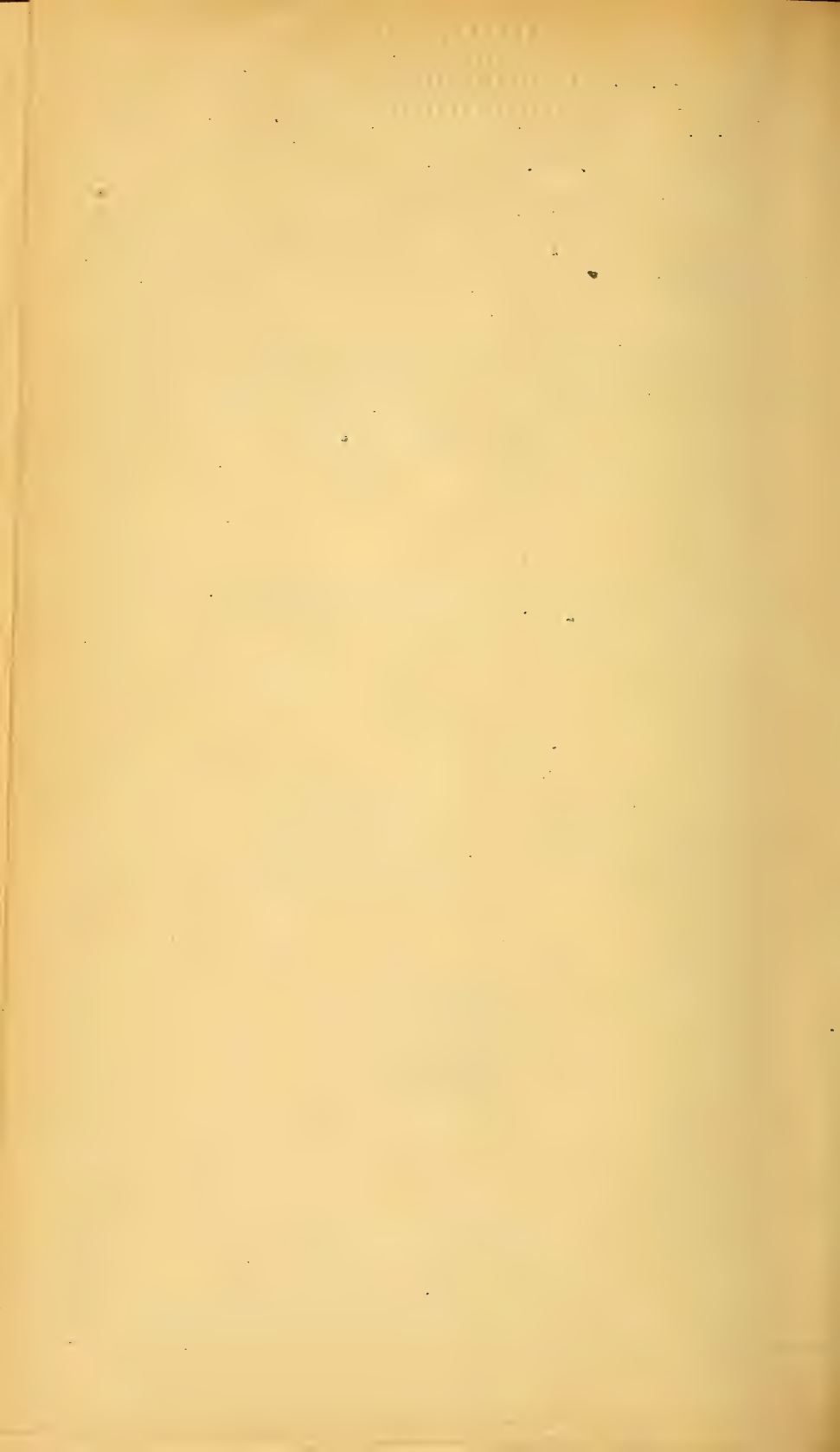
B. R. COAD and T. F. McGEHEE, Entomological Assistants  
Southern Field Crop Insect Investigations

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1917



UNITED STATES DEPARTMENT OF AGRICULTURE  
BULLETIN No. 565

Contribution from the Bureau of Chemistry  
CARL L. ALSBERG, Chief

Washington, D. C.

May 11, 1918

# HOW TO CANDLE EGGS

By

M. E. PENNINGTON, Chief, Food Research Laboratory  
M. K. JENKINS, Assistant Bacteriologist  
and H. M. P. BETTS, Artist

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 575

Contribution from the Bureau of Animal Industry  
JOHN R. MOHLER, Chief

Washington, D. C.



July 23, 1918

STOCK-POISONING PLANTS  
OF THE RANGE

By

C. D. MARSH, Physiologist, Pathological Division

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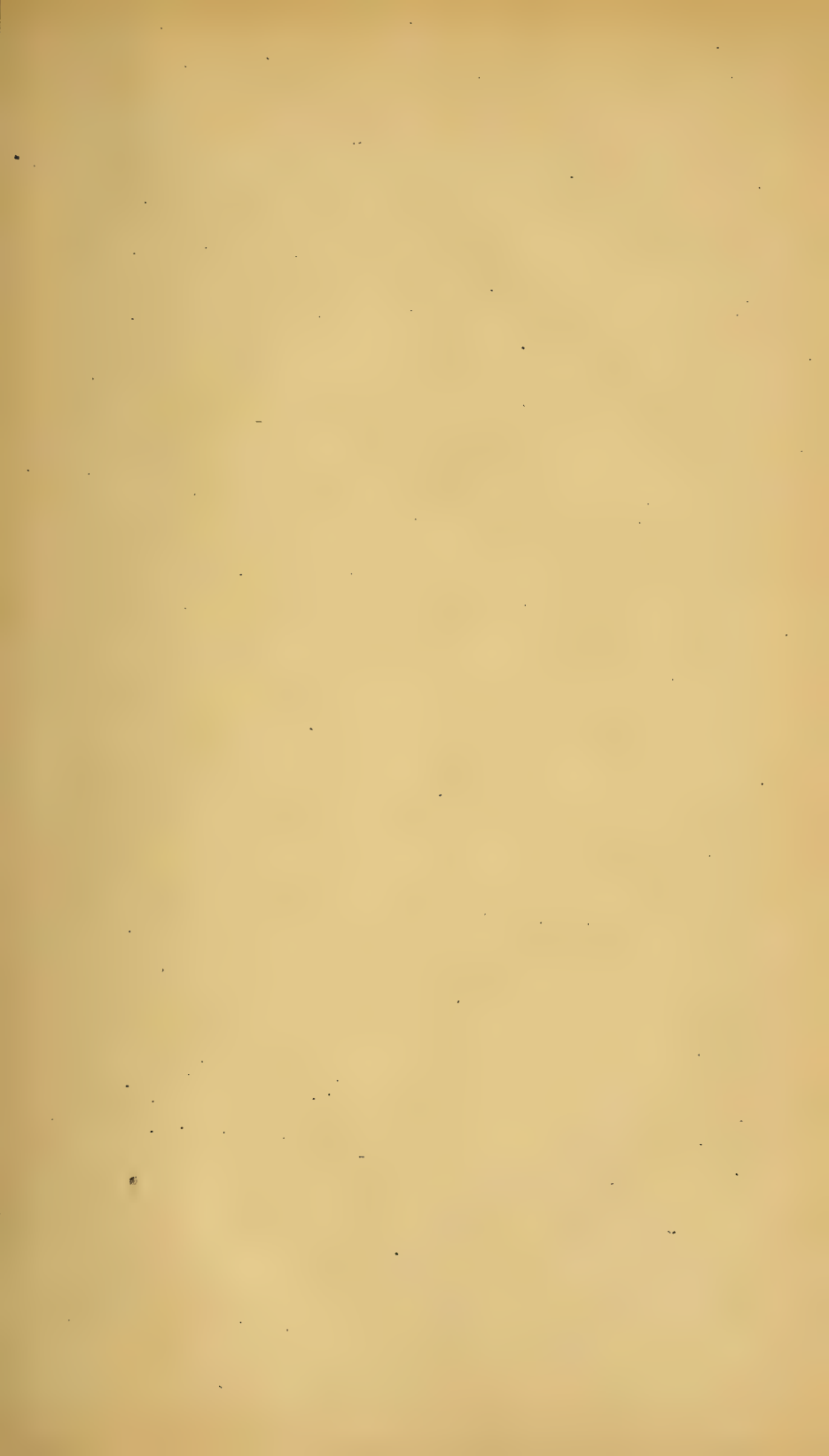
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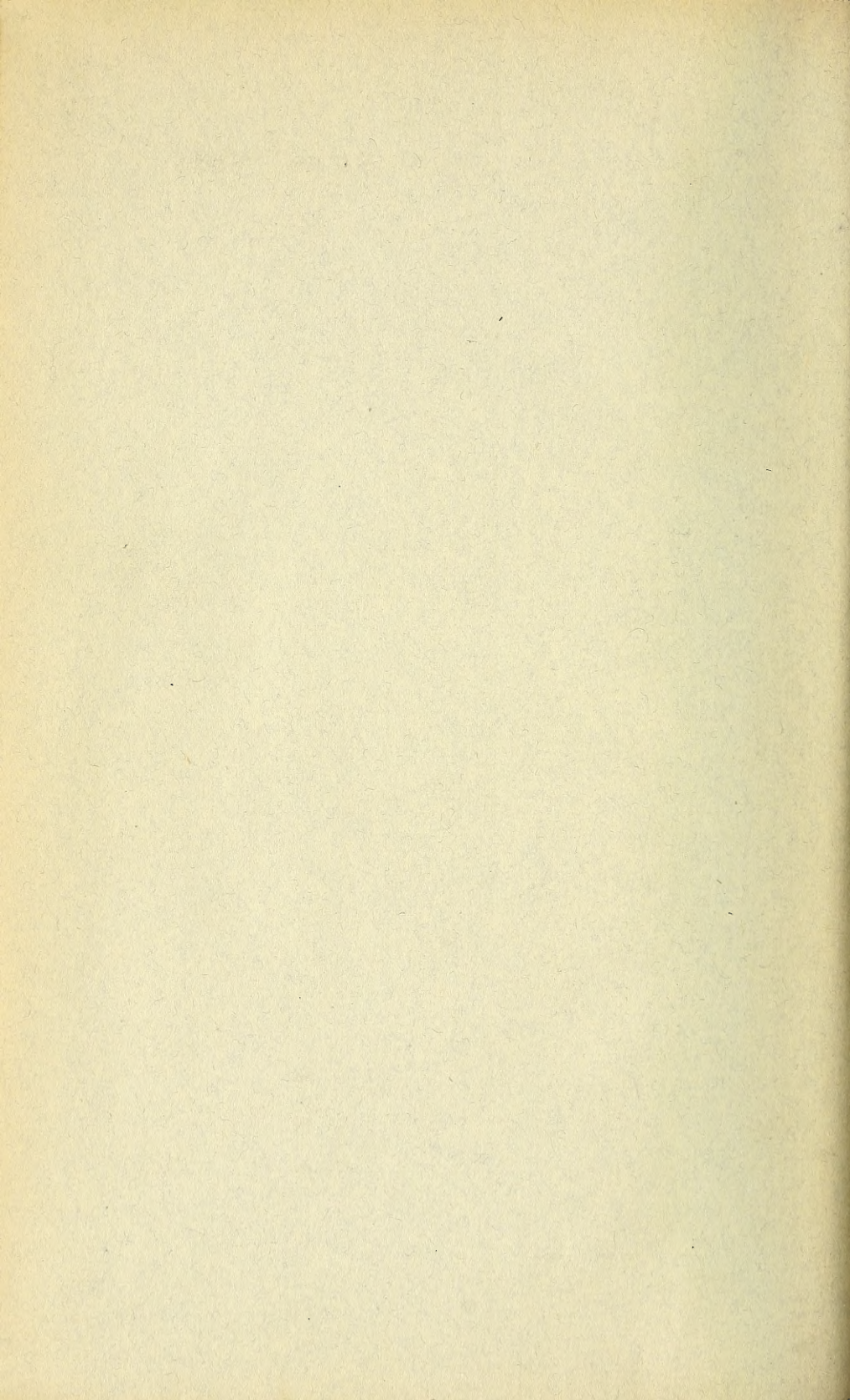
















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